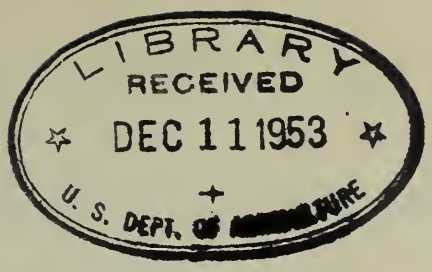

FIRST REPORT

OF THE

COMMITTEE ON SUPPLEMENTAL IRRIGATION IN HUMID AREAS

JANUARY 1952

Members of the Committee:

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Marcus B. Braswell, Farmers Home Administration
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JANUARY 1952

INTRODUCTION

By memorandum dated August 22, 1951 the Assistant Secretary established the Committee on Supplemental Irrigation in Humid Areas and directed it to:

(a) Keep under continuing review the extent and nature of the needs of irrigation agriculture in the humid areas with a view to expand the use of water for supplemental irrigation;

(b) formulate recommendations for extending and intensifying the services of Departmental agencies to assist in meeting these needs; and

(c) report from time to time to the Assistant Secretary on the results of studies and recommendations of the Committee.

In this, its first formal report, the Committee briefly reviews the status of irrigation in the humid areas, presents the results of a survey of current Departmental activities in this field, and submits a series of recommendations.

STATUS OF IRRIGATION IN THE HUMID AREAS

In the decade from 1940 to 1950 the area of irrigated lands in the humid parts of the United States increased from less than 300,000 to almost 800,000 acres; nearly a three-fold increase. These figures do not include the ricelands of Louisiana, Arkansas and East Texas where some 1,600,000 acres were being irrigated in 1950.

Irrigation is practiced in 752 counties in 38 states. Aside from the ricelands, the largest acreage of irrigated land is found in Florida. In 1950 approximately 350,000 acres were under irrigation in that State. In the northeast, the States of New Jersey and Massachusetts report the largest areas of irrigated land; roundly 26,000 and 17,000 acres respectively. The State of Michigan, with almost 14,000 acres under irrigation, leads in the Middle West. In the humid portions of California, Oregon and Washington a total of 155,000 acres are irrigated.

Irrigation is being increasingly used in the humid areas for fruits, vegetables, flowers, pastures and forage production. In areas where drought damages are critical, irrigation of field crops is on the increase.

In Florida surface irrigation predominates, but in the rest of the humid region water is applied by sprinkler systems to nearly 85 percent of all irrigated lands.

The rapid increase in irrigated acreage during the last 10 years has resulted from a number of factors, including: (a) Improved margins of profit from many crops and pasture forage, which has made possible substantial capital outlays for irrigation development; (b) improved transportation and marketing facilities such as deep freezing and rapid shipment by truck, which has made it possible to supply urban centers with more certainty of adequate return on investment; (c) improved irrigation equipment, particularly the portable sprinkler types, and the promotional activities of the manufacturers and distributors of sprinkler equipment; (d) availability of electricity in many rural areas; (e) better understanding of irrigation potentialities brought about by educational processes; (f) provision by the Federal Government of expert technical services to assist farmers in planning and installing irrigation facilities; (g) financial assistance through credit and direct aids by the Federal Government; and (h) Federal and State research.

More detailed information on the status of irrigation in the humid areas may be found in Appendix A, a report submitted to the Committee by the Soil Conservation Service.

SERVICES PROVIDED BY USDA AGENCIES

Agencies of the Department contribute to the development of irrigation in the humid areas by making available educational, technical and financial assistance, credit, and the results of physical and economic research. Moreover, in many areas irrigation is made feasible by the Department's rural electrification program. These services are briefly reviewed in the following.

Educational Assistance

It is to the county agents of the Federal-State Extension system that most farmers first turn for information on agricultural problems. From these well-informed sources the farmer can obtain general advice on irrigation and find out how he can obtain specialized services from other agencies.

To increase the effectiveness of their educational assistance the Federal and State Extension Services provide in-service training. This program

is carried out in cooperation with the Soil Conservation Service. To date it has operated mainly in the arid and semi-arid portions of the country, but a beginning has been made toward extending it into the east by a four day meeting held at Ithaca, N. Y. for personnel of the Extension Services of the northeastern States. In addition to this in-service training the advice of specialists is continuously available to the county agents. Included among the specialists available in the eastern States are forty extension agricultural engineers. Twenty of these are in the southern states, eleven in the north central states, and nine in the northeast.

Technical Assistance

The Soil Conservation Service is the main source of specialized technical assistance. As a part of its regular soil and water conservation program the SCS is assisting land owners and operators to solve their irrigation problems in 31 humid region States. During the fiscal year 1951 it assisted farmers in bringing more than 37,000 acres of land under irrigation in these States. In the aggregate this agency has provided technical assistance for nearly 178,000 acres of humid area irrigated land; or 22 percent of all such land. Most of this assistance has been given since 1945.

The SCS assists in the design and layout of farm irrigation systems and in familiarizing the farmer with proper irrigation methods. This is in addition to the assistance given in the preparation of farm plans and the application of soil conservation measures. It also assists in the planning and construction of group enterprises.

Financial Assistance

To date, incentive payments available through the Agricultural Conservation Program of PMA have played but a relatively small role in encouraging the extension of irrigation in the humid areas. It has been felt that expansion in this direction should be gradual and that a number of important problems require solution before a full-scale program is justified. However, in six humid area States farmers can obtain financial assistance in constructing small reservoirs for the storage of irrigation water. During the six year period 1944-49, inclusive, PMA has helped farmers in these States to build 288 such reservoirs. In the Arkansas and Louisiana rice growing areas assistance in land leveling and ditching is made available. Irrigation farmers in the humid areas along the west coast also receive assistance under the PMA program.

Credit

The Department does not at this time have a credit program especially designed to meet the needs of irrigation farmers in the humid areas.

The Water Facilities program administered by the Farmers Home Administration is limited by law to the arid and semi-arid portions of the 17 western States*. The FHA can advance funds for irrigation purposes as a part of a farm ownership loan made for some other authorized purpose under Title I of the Bankhead-Jones Farm Tenant Act. It can also make disaster loans, and during the drought of 1949 did make a few such loans in the northeast.

The Farm Credit Administration reports that the financing of irrigation systems is an elegible purpose for both production credit association loans and Federal land bank loans. The number of loans made to humid area farmers for this purpose is not known but is probably not large. In most cases the installations financed have been on farms producing high value speciality crops. In this connection it is noted that, in general, it is not practicable to recognize any appreciable additional appraised normal agricultural value in connection with such improvements.

The Rural Electrification Administration makes loans for the purchase of electric pumps and related equipment where farmers wish to provide a supplemental water supply. This service is more fully treated under the heading "Rural Electrification".

Research

The Department initiated research in supplemental irrigation as early as 1900. Most of the earlier work was concerned with the development and operation of equipment and was conducted by the former Bureau of Agricultural Engineering. Responsibility for research in this field was transferred to the Soil Conservation Service in 1939. The Department's earlier publications on supplemental irrigation are listed in Appendix A.

Current research on the problems of humid area irrigation is carried out by BAE, BPISAE and SCS, generally with State cooperation. There is general agreement that the present program must be broadened and intensified to provide a sound basis for expansion of irrigation in the humid area.

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*The Department has recommended to the Bureau of the Budget the extension of the Water Facilities Act in lieu of proposed legislation that would authorize the Bureau of Reclamation to initiate a program in aid of small reclamation enterprises.

The BAE has made studies of the economics of sprinkler irrigation in Wisconsin and in the Pacific-Northwest. It is now cooperating in a study of the economic aspects of water rights problems in the State of Michigan. Other urgently needed studies have been proposed, but it has not been possible to obtain the funds necessary to initiate them.

The BPISAE has conducted orchard irrigation studies. It now has underway research on soil, water, and crop management combinations for corn and forage crops in Alabama and Pennsylvania, and on potato irrigation in Maine. It is also cooperating in a number of State studies, and with the SCS in irrigation investigations in Puerto Rico.

The SCS now has 16 research projects underway that contribute basic information on humid area irrigation. This experimental work is aimed at finding the most effective, practical and economical methods of applying water in various localities, the development of better equipment, and the evaluation of irrigation requirements and benefits. Several reports setting out the results of these studies have been published.

Rural Electrification

Rural electrification multiplies opportunities for supplemental irrigation and the Rural Electrification Administration reports that many of its borrowers are applying for additional loan funds to provide service to pump irrigation installations. Such funds are being provided and this has led to a considerable increase in supplemental irrigation in some areas. It has also led to an increasing demand for special guidance and technical assistance.

The REA has attempted to meet this latter demand by arranging for electric pump irrigation schools at which the electrification advisers of the cooperatives can receive training in the elements of supplemental irrigation. Instructors for these schools are usually provided by the colleges or other agencies of the Department. Outside of arranging for these schools the REA is able to do very little to meet the demand for technical assistance, as it has but a small number of technical personnel experienced in the field of irrigation. The REA cites deficiencies in research data as a further source of difficulty.

PRINCIPAL DEFICIENCIES

The Committee finds that the present activities of the Department do not fully meet needs. Some of the more serious deficiencies are outlined below:

1. Basic data - There is need for more basic data on both the economic and physical aspects of humid area irrigation. Until more is known about the frequency and magnitude of soil moisture deficiencies in the humid regions, the increases to be expected in the yields and in net incomes, the best methods of irrigation for various crops and

soils - to mention but a few important factors - the Department cannot provide irrigation farmers with the advice and services they should have. There is a particularly urgent need for interpreting the results of both experiments and experience, and making these interpretations readily available to technicians and farmers.

2. Credit - As previously pointed out the credit programs of the Department are not designed to meet the specific needs of the humid area farmer who wishes to install irrigation facilities. Legislation will eventually be required to make good this deficiency.

3. Services - There is need for general intensification of the educational, technical and financial services available to farmers irrigating, or contemplating the irrigation of, lands in the humid areas. This need cannot be fully met until the basic data deficiency is overcome. Nevertheless, many farmers are making large investments in supplemental irrigation and it is incumbent upon the Department to give them, at any particular time, the advantage of the very best advice available. The Committee feels that enough is known to justify an intensification and expansion of present services.

4. Water Rights - The Committee is particularly concerned over the fact that the water laws of the humid area States do not, in general, adequately protect the considerable investments that farmers must make if they install irrigation facilities. Until these farmers can obtain firm rights to continued use of water it will be impossible to develop the full potentialities of irrigation in these States.

RECOMMENDATIONS

The Committee recommends:

I. A general broadening and intensification of the Departments activities in the collection, analysis and publication of basic information bearing upon irrigation in the humid areas. To this end it is further recommended:

   A. That the agencies of the Department responsible for such activities immediately institute a review thereof to determine that everything possible is being done to solve the problems of irrigation in the humid areas. In this, special attention should be given to bringing together, interpreting and publishing data already available.

   B. That appropriate agencies of the Department undertake at the earliest possible moment the following special projects:

(1) A survey and analysis of existing data to determine water requirements for irrigation in humid areas.

(2) A study of water yields in humid areas.

(3) Research to determine soil and crop management practices for use in supplemental irrigation in humid areas.

(4) Research on the economics of supplemental irrigation in humid areas.

The following agencies have indicated that they are willing to assume primary responsibility for these special projects:

Project	Agency
1	Soil Conservation Service
2	Soil Conservation Service
3	Bureau of Plant Industry, Soils and Agricultural Engineering
4	Bureau of Agricultural Economics

The nature of each of these special projects is more fully brought out by the work outlines accompanying this report as Attachments I-IV inclusive.

The Committee proposes to give further attention to basic data requirements and may suggest additional special studies in subsequent reports.

To shed further light upon the need for basic information a report of a Research Panel on Supplemental Irrigation, dated January 8, 1951, accompanies this report as Attachment V.

II. Strengthening of USDA programs providing educational, technical and financial assistance to irrigation farmers in humid areas. To this end it is urged that the agencies responsible for these service programs subject them to careful review to discover ways and means of better meeting the problems of humid area irrigation.

At this time the Committee has no detailed recommendations to make in this connection. However, it suggests that when the agencies review their programs special attention be given to the possibilities for:

(a) Expanding present training programs (short course schools and other in-service training devices) through which county agents, farm planners and others are enabled to give farmers better advice on supplemental irrigation in humid areas.

(b) Increasing the number of humid area irrigation practices for which financial assistance is made available. As a first step in this direction conservation needs data should be expanded to include additional irrigation needs in the humid areas.

(c) Providing additional irrigation specialists in certain problem areas.

(d) Making it easier for humid area farmers to obtain irrigation equipment subject to government controls.

III. That steps be taken to establish within the Department a special program for the provision of loans and technical sssistance to land reclamation enterprises of small and intermediate size. This program should service all forms of land reclamation (including drainage and land rehabilitation)in all parts of the Nation.

Attention is called to the fact that, as a result of the introduction of H. R. 2646, both the Congress and the Office of the President are actively considering the establishment of such a program; and that an effort is being made to secure for the Department the legislative authorities contemplated. This effort has led to the formulation by the Department for consideration by the Bureau of the Budget of the attached policy statement (Attachment VI). The Committee feels that the Department should persist in its efforts to secure these legislative authorities and that its efforts in this direction should be accorded the full and active support of all of its agencies.

If it is found that legislation of the nature now being sought is not likely to be forthcoming in the near future, other means of implementing a combined credit and technical assistance program should be considered. For example, it might be found advisable to limit the legislative effort to a request for relatively minor amendments to present credit authorities, and to pool these with existing technical assistance authorities as a basis for such a program.

In the event it is decided that such a broad program of combined credit and technical assistance should not be attempted at this time, steps should at least be taken to have present credit legislation amended in such a way that it better meets the needs of humid area farmers desiring to place land under irrigation.

IV. A special study of the water laws of humid region States with a view to defining and proposing solutions for the many important legal problems that have arisen, or are expected to arise, in the development of irrigation in these States.

This study is outlined in Attachment VII. A review of Appendix B, "Legal Principles Relating to Irrigation in the Eastern States", will show why such a study is needed.

V. The preparation of a bulletin bringing together in the simplest possible terms the results of research and experience on irrigation in the humid areas. This bulletin should be designed to meet the needs not only of farmers, but also of personnel of the Department called upon to give farmers general advice on humid area irrigation.

If this recommendation meets with approval the Committee proposes to establish a small task force to consider ways and means of preparing and publishing such a bulletin and to subsequently submit a definite proposal for consideration and approval.

VI. Close cooperation with the Land Grant Colleges in a nation-wide inventory of the problems and needs of irrigation agriculture.

The Committee notes with satisfaction the arrangements that have already been made for such cooperation and urges full support thereof by all agencies of the Department.

ATTACHMENTS

TO THE FIRST REPORT OF THE

COMMITTEE ON SUPPLEMENTAL IRRIGATION IN HUMID AREAS

JANUARY 1952

I. Work Outline - A survey and analysis of existing data to determine water requirements for irrigation in humid areas.

II. Work Outline - A study of water yields in humid areas.

III. Work Outline - Research to determine soil and crop management practices for effective use of supplemental irrigation in the humid areas of the United States.

IV. Work Outline - Research on the economics of supplemental irrigation in the humid areas.

V. Report of Research Panel on Supplemental Irrigation - January 8, 1951.

VI. Statement of policy proposed as a basis for a program of assistance to land reclamation enterprises.

VII. Work Outline - A study of legal principles relating to water rights in the eastern States.

ATTACHMENT I
To the First Report of the
Committee on Supplemental
Irrigation in Humid Areas
January 1952

WORK OUTLINE

FOR

SURVEY AND ANALYSIS OF EXISTING DATA

TO DETERMINE WATER REQUIREMENTS FOR IRRIGATION IN HUMID AREAS

Foreword

At the very outset of the Committee's discussions it became clear that there is an urgent need for better information on irrigation requirements in humid areas; that is, for an answer to the question: "How often and how much?" Such information is essential in designing irrigation systems. It is also necessary in determining whether supplemental irrigation will pay for itself under given conditions.

Objectives

The objectives of the undertaking proposed herein may be summarized as follows:

A. To bring together available information, to subject it to analysis, and to present estimates of irrigation water requirements for selected soils, crops and climates.

B. To critically evaluate existing information and experimental work underway, and on the basis of this evaluation recommend additional research, or the reorientation of present research.

Outline of Proposed Procedure

It is proposed:

1. That an especially qualified water expert be assigned full time to the undertaking, and that he be provided with: (a) access to experts in all agencies for advice and general assistance; (b) stenographic assistance, and; (c) assistance, as needed, in making routine calculations.

2. That pertinent information be assembled, with all agencies of the Department contributing fully.

3. That these data be analyzed in such a way as to arrive at estimates of irrigation requirements for: (a) selected climatic regions; (b) typical soils, and (c) important crops.

4. That two general approaches be followed: (a) Analysis of direct evidence, such as lysimeter data, continuing soil moisture records, and records of crop yields and crop failures; (b) indirect approaches, such as by the calculation of soil moisture deficiencies from rainfall, infiltration and evapo-transpiration data, or by the correlation of irrigation requirements with rainfall, records of evaporation from water surfaces and/or other factors. The estimates obtained by such indirect methods will, of course, be approximate. Nevertheless, they should be of great value in the absence of long-term records of soil moisture for all of the conditions considered important.

5. That the detailed plan for the study be developed by the technician assigned responsibility for it in close consultation with the experts of the interested agencies of the Department and that it be reviewed by the Committee in the early stages of the undertaking.

6. That the study result in two principal documents;

   (a) A manual containing, in a form for convenient use by field technicians and economists, estimates of irrigation requirements for various climates, soils and crops.

   (b) A report setting forth important deficiencies in the existing data and outlining the studies that appear to be required to make good these deficiencies.

7. That if, in the course of the undertaking, it is found that an extension would be worthwhile, an interim report be submitted at the end of the year setting out findings to date, recommending any necessary further work and outlining a plan therefor.

Financial Requirements

On the assumption that all agencies of the Department will freely contribute data and advice, and provide some assistance in the making of routine computations, it is estimated that this project could operate for one year on an allotment of approximately 25,000 dollars.

If the project should be extended beyond one year the cost would depend upon the scope of the plan mentioned in 7 above.

Prepared by the following Working Group:

C. P. Barnes, ARA; T. B. Chambers, SCS; H. L. Cook, Sec.; C. W. Crickman, BAE

ATTACHMENT II
To the First Report of the
Committee on Supplemental
Irrigation in Humid Areas
January 1952

WORK OUTLINE
FOR
A STUDY OF WATER YIELDS IN HUMID AREAS

Objective

The objective of the proposed study is to bring together available information, to subject it to analysis and to make available for use in the planning of supplemental irrigation systems, data on the water yield of small watersheds of various physical characteristics located in various parts of the humid region.

Procedure

This study would be carried out in conjunction with, and will in some degree complement, the study of water requirements outlined in Attachment I.

It is proposed that an especially qualified hydrologist be assigned responsibility for the study and that he be provided with: (a) access to experts in other agencies of the Department for advice and general assistance; (b) stenographic assistance, and; (c) clerical assistance, as needed, in making routine calculations.

Available water yield data would be analyzed and related to drainage area characteristics and to climatic factors. The results would be summarized in a form suitable for inclusion in manuals for the use of those planning irrigation systems. They would also constitute an important contribution to scientific hydrology.

An effort would be made to complete this study in one year. If an extension should be found necessary, an interim report would be issued at the end of the year and a plan submitted for any further work considered necessary.

Financial Requirements

On the assumption that the study of water requirements (Attachment I) goes forward simultaneously, it is estimated that cost of the first years work would be 25,000 dollars.

ATTACHMENT III
To the First Report of the
Committee on Supplemental
Irrigation in Humid Areas
January 1952

WORK OUTLINE

FOR

RESEARCH TO DETERMINE SOIL AND CROP MANAGEMENT PRACTICES

FOR USE IN

SUPPLEMENTAL IRRIGATION IN HUMID AREAS

The Problem

The 31 Eastern States comprise, roughly, the humid region of this country. In this area, supplemental irrigation is used primarily to make up for poor distribution of rainfall during the growing season. Although this is a humid area, droughts during the growing season are common.

Two of the most characteristic features of supplemental irrigation are:

1. When it is time to irrigate one field, it is time to irrigate the whole farm. Rotational use of water from field to field is feasible to a far less degree than in the West.

2. Soil and topography are such that surface ditches and furrow irrigation are usually not feasible.

Supplemental irrigation in the humid regions has had an interesting, though sporadic history. For 40 or 50 years there have been a few hundred acres irrigated in nearly all of the eastern states -- and in some periods the figure grew to a few thousand acres. As a matter of fact, this interest in irrigation has gone through several cycles of resurgence. The current development of supplemental irrigation has been so rapid that its acreages were not even recorded in the agricultural census prior to 1939. Yet there was at that time almost 300,000 acres under supplemental irrigation. Recent information indicates that the rate of increase has been stepped up since 1945. Areas in which only a few hundred acres of specialty crops were being irrigated a few years ago now have thousands of acres under irrigation covering many different kinds of crops. The total amount of land now being irrigated in the East is estimated at almost 800,000 acres. This is in addition to approximately 1,600,000 acres on which rice is grown.

The irrigation equipment companies have played a dominant role in the development of supplemental irrigation, and they have many capable men on their staffs. The agricultural engineers in the research institutions have also been awake to the problem, and have work under way. Supplemental irrigation has developed, for the most part, with little agronomic research

guidance. There are exceptions and activity in this field is increasing. Farmer interest and engineering competence, however, have been the two major factors to date.

The role irrigation ultimately will play in the East is not yet clear. Just how much can be done with a combination of fertilizer, improved varieties, better cultural practices, and supplemental irrigation, remains largely to be proved. The cropping systems and pattern of land use may well differ from present land use. Sound agronomic research guidance will be required on an intensified scale if supplemental irrigation is to be used efficiently.

Plan of Work

An intensive series of field experiments will be devoted to obtaining direct answers to these four questions:

1. How much water is required at each stage of growth, for important pasture, vegetable, and field crops? How do these requirements vary with soil, climate, and fertilizer use?

2. What are the fertilizer rate, time, grade and placement requirements when lack of moisture no longer limits crop production? What additional disease and insect control measures are necessary?

3. What are the methods of land preparation, crop varieties, dates of planting; and cultural practices required for most efficient use of supplemental irrigation?

4. How can crop residues, green manure crops, and other soil and water management practices be balanced to maintain good soil structure and permeability to water and crop roots?

Location of these field experiments will be determined in consultation with the Soil Research Committees of the Southern, Northeastern, and North Central Land Grant College regions. The experimental locations will be representative as to soil and climate, in areas where soil and water resources promise sizable future expansion of supplemental irrigation. It is likely that the following five major areas will be represented.

1. Valley and terrace soils of the Northeast.
2. Coastal soils of the Mid-Atlantic states.
3. Piedmont and lower coastal plain soils of the Southeast.
4. Valley and upland soils of the Mid-South.
5. Bottom-land and terrace soils of the Mid-West.

Cooperation

This research program will be focused on the agronomic problems of supplemental irrigation, and will be conducted by teams of soil and crop specialists from the appropriate Agricultural Research Administration research agencies in cooperation with agronomists of the State Agricultural Experiment Stations. This program will be developed in cooperation with irrigation specialists of the SCS and the State agricultural experiment stations, and will be closely integrated with existing irrigation engineering studies wherever possible.

Financial Requirements

The studies to be undertaken will seek solutions to complex soil, water and crop management problems. Both field and laboratory facilities will be required at several locations, and competent technical staffs will be required with training and experience in soil fertility, soil physics, plant physiology and nutrition, and disease control.

By making maximum use of existing facilities, the financial requirements for professional and subprofessional personnel, equipment, supplies and operating expenses will approximate $50,000 per location. Five locations would give a minimum sampling of geographical areas where supplemental irrigation is assuming great importance, requiring a total annual budget of $250,000. This project should run for at least five years.

Prepared by: R. Q. Parks, BPISAE

ATTACHMENT IV
To the First Report of the
Committee on Supplemental
Irrigation in Humid Areas
January 1952

WORK OUTLINE

FOR

ECONOMIC RESEARCH ON SUPPLEMENTAL IRRIGATION IN THE HUMID AREAS

Foreword

Supplemental irrigation has been expanding at a relatively rapid rate in recent years on farms in the humid areas of the country. Increasing numbers of farmers have obtained remarkable response in higher yields and in better quality of crops through supplementing natural moisture. In the early years of the development of supplemental irrigation in the humid areas, it was used principally for rice, citrus fruit and high-value truck crops. Irrigation of other types of crops, including field crops of various kinds, is now being practiced by some farmers. Equipment manufacturers have developed new irrigation equipment, especially the portable sprinkler type, which is well adapted for supplementary irrigation; and apparently under current price relationships the installation of such equipment is profitable for many farmers. The extent to which supplemental irrigation will be profitable in the future, and the extent to which it may be expected to expand further, depends upon a number of conditions, among which are: Changing price relationships; seasonal and yearly variations in rainfall and other climatic conditions; the improvement in yields and quality of different crops that can be expected under different practices and soil types; and the solution of water right and supply problems.

Information is needed regarding the extent of the present use of supplemental irrigation and the conditions under which it may be expected to be profitable. An economic evaluation is needed of the additional costs and returns, and of other farm management problems associated with the use of supplemental irrigation. An analysis needs to be made of the investment requirements and costs of operation under different conditions and the probable returns on such investments in normal, below-normal, and above-normal rainfall periods.

As irrigation is expanded in eastern Unted States, problems may arise with respect to availability of water supplies. Farmers may need to consider group development of water enterprises or river basin development projects. Institutional arrangements of the type and kind needed to facilitate this new development or to prevent conflicts from arising have not been developed in many of the Eastern States. Appraisals need to be made of the present legal and institutional barriers to the development of irrigation and the utilization of the vast potential water supplies in the East for this purpose.

Although much research remains to be done in the natural science fields before completely adequate economic appraisals can be made as to the profitability of supplemental irrigation under all conditions, sufficient experience has already been accumulated by many farmers to warrant thorough economic studies in a number of areas and under different conditions.

Studies Proposed

1. General reconnaissance of present status of supplemental irrigation in humid areas. - The 1950 Agricultural Census will show by counties the the number of farms and the acreage of irrigated land in farms in 1949, and the number of farms and the acreage of land irrigated by sprinklers. This information will provide the basis for selection of a scientific sample of farmers practicing supplemental irrigation. Mailed questionnaires could be sent to this sample of farmers to develop, relatively quickly and inexpensively, a general picture of conditions, results, and problems of supplemental irrigation. Information would be obtained such as the following: (1) Kinds of crops irrigated; (2) acres and yield of crops irrigated last year; (3) number of irrigation applications and amount of water used; (4) estimated increase in yield of each crop as a result of irrigation; (5) kind of installation and estimated investment cost; (6) date supplemental irrigation first practiced and number of years that crops have been irrigated; (7) sources of water supply; and (8) water rights problems encountered, if any.

   Such a survey would give the Department for the first time some much needed information on extent and use of supplemental irrigation. The information would be useful for operating programs, for informational programs, and for location of research and other more detailed studies.

2. Detailed economic studies of cost, returns, and farm management problems related to use of supplemental irrigation. - The objective of these more detailed studies would be to explore the conditions under which supplemental irrigation has been profitable and to make an economic evaluation of costs and returns, and of other farm management problems in selected areas. Studies should be made first for different conditions in selected areas in the Lake States, in the Southeast, and in the Northeast in cooperation with State Experiment Stations. Conditions in other parts of the humid region would be studied later.

   Farmers in selected areas who use supplemental irrigation would be interviewed to obtain a schedule of information concerning their operational experiences and additional costs and additional returns associated with the use of supplemental irrigation on different crops and pasture. Important items of operations are: Kind of land adapted to irrigation, location of land with reference to water supply, sources of water, kinds of equipment used and installation costs, quantity of water used

and frequency of applications, rates of fertilization, irrigation crew, cost per acre for irrigating and associated practices, and increases in yield and improvement in quality of crops. Farm budget analyses would be made for selected typical farms to determine the potential effects on farm organization, and on costs and returns for various combinations of crops under varying cost and price relationships. In the development of the budgets, the farm management workers would enlist the cooperation of agronomists, agricultural engineers and other specialists who have conducted experimental research on supplemental irrigation. The budgeted potential benefits and costs would be tested by enlisting the cooperation of selected farmers who are willing to carry out supplemental irrigation operations in accordance with the budgeted systems of farming under the guidance of research and extension workers.

3. Institutional barriers to the further development of supplemental irrigation. - The objective of this research would be to explore and evaluate such aspects of water use problems as institutional and existing legal rights to flowing streams and groundwater that have a bearing upon the potential development and economic feasibility of supplemental irrigation in the humid States. An exploratory study of this kind has been made by the Bureau of Agricultural Economics in Michigan, but the appraisal needs to be carried further and undertaken in a number of other areas.

In each of several selected areas, probably the same areas as those indicated under item (2) above, an inventory would be made of the present extent of supplemental irrigation development in relation to existing and potential sources of water. From locally informed persons and other sources, information would be obtained in regard to existing competition for water supplies by water users and the prospects of any emerging conflicts for use of available water supplies as irrigation is increased. Also, from these general sources information would be obtained on the extent to which group enterprises have been established to provide water supplies and to take care of associated drainage requirements. The problem of water rights would be studied on a State-wide basis in cooperation with the Office of the Solicitor with the view of determining feasible arrangements for clarifying the farmers' rights to use of water for irrigation purposes under the various competitive conditions found in each of the areas studied.

4. Economic interpretation of experimental results. - Considerable farmer experience and other information is now available for economic research on supplemental irrigation. In addition, new experimental data are, or will become, available that have not yet been used by farmers such as the response of crops to varying amounts of water applications under different soil and rainfall conditions or the crop yield response of various combinations of water and fertilizer or other practices. Economists and the natural scientists need to cooperate in developing and evaluating such information. The profitability of

various input-output relationships should be tested by measuring the effects on farm costs and returns with different farm budgets. Such cooperative research will increase the reliability of recommendations made to farmers under different environmental and economic situations.

Cooperation

It is anticipated that the inventory of irrigation needs proposed to be undertaken by the Land Grant Colleges will be designed to secure part of the information called for by the above study outlines. To the greatest possible extent, therefore, it is proposed to secure such information as a part of the Land Grant College inventory. It is also proposed to seek the cooperation of all interested agencies of the Department in carrying out these studies.

Financial Requirements

Adequate appraisal of the economic problems of supplemental irrigation and conduct of enumerative surveys on extent and status of present development will require an annual budget of about $150,000.

Prepared by: C. P. Heisig, BAE

ATTACHMENT V
To the First Report of the
Committee on Supplemental
Irrigation Humid Areas
January 1952

January 8, 1951

To: Dr. Omer W. Herrmann, Assistant Research Administrator

From: Carleton P. Barnes, Research Coordinator

Subject: Need for research on supplemental irrigation

Our research panel on supplemental irrigation in the humid region has for the past eleven months been considering research needs in this field.

We first reviewed research projects under way or recently completed. We found a good many projects, ranging all the way from simple trials to rather complex experiments involving several variables. Work is going on in nearly all parts of the region. At least limited studies are being conducted on nearly all aspects of the problem in one place or another although fertility-moisture relationships are receiving less emphasis than the engineering aspects of supplemental irrigation.

In general, the experiments show substantial crop yield response in dry years but little or none in seasons of abundant moisture, as one would expect. Few of the projects have run long enough to afford conclusive evidence on economic feasibility. It seemed probable that if an experiment could be run long enough to sample much of the diversity of seasonal moisture conditions likely to occur at a station, expectable yield responses over a long time period might be extrapolated by using long-time weather records which disclose frequency of occurrence of different seasonal moisture patterns. If this were possible, experiments could be terminated sooner than otherwise. Therefore, we reasoned that a necessary complement to experimental data would be the graphic presentation of seasonal moisture pattern frequencies for weather stations all over the East. It was hoped that this might be manipulated so as to reflect frequency of critical moisture patterns for specific crops. It was suggested that correlation of crop behavior data with weather data from experiment records would yield critical moisture condition values for individual crops but agronomists of BPISAE reported inadequate data to develop such values. Consequently, presentation of seasonal moisture frequency data will probably have to be in terms of arbitrarily selected values.

One problem of experimental research in this field is that of selecting experimental conditions such that the research results will have prediction value for many farms. That is, the soils of the experiment should be kinds found on many farms, and the availability of water supply should be equivalent to that on many farms. Because of the almost innumerable

variety of conditions affecting water supply particularly, it seems likely that many current and past experiments may not represent conditions of wide occurrence, and that for ample geographic coverage more experiments might be needed. However, this immediately raises a question of how much can justifiably be expended for experiments of limited prediction value.

The panel could not, without taking more time than was available to it or to the agencies represented, make a study of each current or recent project to find out the extent to which the experimental conditions are representative of conditions that will be widely met by farmers. It seems probable from the information we have that many of the experiments are on kinds of soils that are of wide extent.

The panel considered the possibility of using some kind of inventory procedure by which areas could be delineated, within which supplemental irrigation experiments on representative locations would seem to have application to many farms. We considered the need to inventory water supplies in such a way that areas having so poor a supply that relatively few farms might use irrigation could be delineated and avoided in choosing locations for experiments. Also, we thought of trying to map out areas where a large percentage of the land had soil and topography favorable to irrigated cultivation and where high value crops tended to be grown.

We tried out such an inventory procedure for Georgia, using only such information as could be had easily. We found that it was of some help in determining the areas in Georgia where experiments on representative locations would likely have wide application. We were, however, not sure that the procedure was thorough enough to have final weight in determining experimental locations. In addition, it did require expenditure of considerable time by a field office of one of the agencies. Considering these circumstances, as well as the probability that a state experiment station would normally use a similar procedure in judging where to locate experiments, we did not recommend the general inventory of land and water availability as a necessary task in planning experiments.

We concluded, however, that an inventory procedure of this kind might be justified as part of a full-scale regional planning activity which undertakes to study the whole water supply and to consider the competing claims upon it, e.g., the activity just being started in the New England-New York area.

We considered whether the panel should undertake to suggest the design or working plan of a typical experiment in supplemental irrigation, and concluded this was more appropriately done by the regional soil research subcommittees on supplemental irrigation.

We considered whether we should recommend one or more specific experiments in particular places and decided we were not prepared to do it.

We considered the need to obtain information by survey, on the experience of farmers with supplemental information. We concluded this was an important source of data which would have prediction value, if properly interpreted in the light of knowledge being gained by experiment. Such surveys should cover sources of water, kind of irrigation systems and equipment, amount and timing of water used, as well as crop response. BAE has a project of this general kind planned and the panel endorses it.

We have considered the need to study the water laws of Eastern states to determine whether they should be revised so as to afford reasonable protection to rights to the use of water for irrigation purposes. We have had rather general agreement on the need for such a study. A representative of the Solicitor's Office is a member of our panel. We considered recommending that the Solicitor's Office draft a model state water law for consideration of states interested in providing greater protection to rights to the use of water for irrigation than is given by existing state laws. The representative of the Solicitor's Office pointed out, however, that the work involved in drafting such a law would be so great, including the necessary research, that we ought to be dead sure of the need to do it before we recommend that it be undertaken by that office. We, therefore, considered the need to obtain the judgment of state officials concerned with water, e.g., officials of Conservation Departments, as to (1) whether the problem was worthy of special study, (2) what study is already under way, and (3) whether the state would welcome suggestions from the Department regarding a model state water law. We thought also of asking the judgment of Experiment Station directors on the urgency of need for such a study. It has been ascertained that the President's Water Policy Commission did not canvass state agencies to ascertain their judgment as to the importance of revising state water laws.

In summary, the panel recommends:

1. That the Department develop a statistical device for portraying the probable frequency of defined weather pattern classes by selected short intervals, using weather data from all stations of long record. This would furnish a means by which the results of relatively short-term experiments disclosing crop yield response to applied moisture, might be related to long-time weather pattern frequency data so as to predict the frequency of specific crop yield responses from irrigation over a long period.

2. That the Department obtain, by the survey method, information on conditions and results of supplemental irrigation as practiced, sampling farms and group enterprise, if any, in all of the areas where supplemental irrigation has been used on a good many farms. That BAE seek funds for work of this sort substantially as proposed in the outline for work project RM:b-605.

As a first step in this process, it is recommended that BAE undertake a survey by questionnaire, mailed to a sample of farmers who are practicing supplemental irrigation in the East, as shown by the 1950 census, ascertaining such facts as (a) Date supplemental irrigation first practiced,

(b) number of years since beginning that crops have been irrigated, (c) acres and yield of crop irrigated last year, (d) sources of water supply, (e) number of applications and amount of water used, (f) water right problems encountered, if any, (g) estimated cost of installation, and (h) estimated increase in yield of each crop as a result of irrigation.

3. That additional experiments to measure the effect of controlled variable conditions on response to applied water be undertaken at locations where the circumstances of soils and water supply are equivalent to those likely to be found on many farms.

4. (a) That we make a canvass of state water conservation agencies to ascertain their judgment on the following questions:

(1) Do the existing water laws of the state afford reasonable protection to rights to the use of water for irrigation?

(2) Has a study of these laws been made looking toward their revision? Should such a study be undertaken? Are there plans for making such a study in your state?

(3) Would it be helpful to your agency if the United States Department of Agriculture should draft for its consideration a model state water law designed to give reasonable protection to rights to the use of water for irrigation?

(b) That we canvass State Agricultural Experiment Station Directors on questions (1) and (2).

(c) That the Solicitor's Office draft a model state water law, provided the results of the above canvass indicate the desirability of such action.

5. That an inventory of supplementary irrigation possibilities in the New England-New York area be undertaken as part of the agricultural program to be planned as part of a resource development program for that area.

ATTACHMENT VI
To the First Report of the
Committee on Supplemental
Irrigation in Humid Areas
January 1952

OUTLINE OF POLICY
FOR
A FEDERAL PROGRAM IN AID OF SMALL RECLAMATION ENTERPRISES
As Proposed by the Department of Agriculture
January 22, 1952

1. Objectives

The objectives of a Federal program in aid of small reclamation enterprises should be:

(a) To increase the production of needed agricultural commodities, in proper balance and at the proper time, by encouraging the development of new, and the improvement of existing, small reclamation enterprises that will constitute permanent and efficient additions to the Nation's agricultural plant.

(b) To encourage the assumption of the maximum possible degree of responsibility for the reclamation of land by the primary beneficiaries, and assumption of any essential public responsibility at the lowest level of government capable of discharging that responsibility.

(c) To create as many new opportunities as possible for farm families to achieve an adequate level of living.

(d) To contribute to the efficient use of land and water resources for agricultural production.

2. Scope

Under this program assistance should be available to all forms of reclamation enterprises (irrigation, drainage, land clearing or other) located in any part of the Nation.

3. Nature of Federal Assistance

Under this program the Federal Government should provide, upon request:

(a) Loans, as necessary to supplement investments from the borrowers' own funds, up to the full amount required to construct or rehabilitate small reclamation enterprises, upon a showing that adequate credit cannot be

otherwise obtained on reasonable conditions. The terms of such loans should require repayment by variable annual payments in the shortest period consistent with repayment ability, but in no event exceeding 50 years.

(b) Loans to State executive agencies empowered by State law to:

(1) plan, construct and/or operate small reclamation projects, or

(2) extend credit to reclamation enterprises.

Such loans should not exceed 50 percent of the cost of the work to be undertaken in connection with the particular enterprise for which the loan is requested. The repayment period should not exceed 50 years and repayment should be guaranteed by the State.

(c) General technical advice and consultation at no cost to enterprises requesting or receiving loans under (a) above.

(d) Technical services (over and beyond assistance that may be available free of charge under public programs in operation at the time, . . . including the preparation of plans and the supervision of construction) to enterprises receiving loans under (a) above, upon a showing of necessity and agreement by the enterprise to assume the full cost of such assistance.

4. Loan Limitations

Loans made under this program should be subject to the following limitations:

(a) The total amount loaned to any single enterprise should not exceed $1 million*.

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* These limitations on size of enterprise are included here because the Bureau of the Budget has expressed a desire to limit discussion at this time to small enterprises. The Department of Agriculture believes that a preferable approach would be to explore the full field of usefulness of a Federal program of credit and technical assistance. The Department is convinced that in reclamation, primary responsibility should, in general, rest upon the organization of direct beneficiaries and that much larger enterprises than those herein classed as "small enterprises" can best be carried out by such an organization if credit and technical assistance is made available. The need for public projects (Federal or State) is, in the opinion of the Department, very limited. In fact there is now no evidence that such public projects will ever be needed in the eastern United States.

(b) Loans should not be made for the establishment of any new enterprise that will embrace more than 5,000 acres of reclaimed land when fully developed*.

(c) Loans should not be made to Federal projects for the reclamation of land, or to parts thereof, which are indebted to the United States, unless the agency responsible for collection of such indebtedness, and the agency responsible for loans under this program, mutually agree that such a loan is desirable.

(d) Loans should not be made to enterprises able to secure such loans from a State agency unless the making of the loan is agreeable to that agency.

(e) Loans should not be made to enterprises which embrace, or would embrace, any part of a reclamation project proposed in a report submitted by a Federal agency to the State for review, and which has been approved by the State, while this project is still under consideration by the Federal agency; but this shall not prevent the making of such a loan when the Federal agency responsible for the report, and the agency responsible for loans under this program, mutually agree that the loan is desirable, and in any event this limitation shall not remain in effect for more than three years after approval of the report by the State.

5. Requirements for Eligibility

The enterprises to which loans are made under this program should meet the following requirements:

(a) Be in harmony with regional and national requirements for the production of agricultural commodities.

(b) Be in harmony with approved river basin or regional plans.

(c) Be capable of producing total benefits in excess of total costs.

(d) Be capable of repaying the amount of the loan, including the interest thereon.

(e) Be in accord with sound engineering principles.

(f) Provide for effective use and conservation of land and water.

(g) Provide that lands on which agricultural commodities are not produced, or are produced in relatively small quantities (25 percent or less of the value of the expected productivity), shall be developed as farm units:

(1) Capable of providing a moderate income for a representative farm family with no other source of income.

(2) Of such size that they may be managed as independent units for which a representative farm family could normally supply a major part of the labor required and in the operation of which such a farm family would be efficiently and reasonably fully employed.

(Note: Inasmuch as under a loan program of the kind proposed the enterprise would repay the entire amount loaned by the Federal Government, including interest, acreage limitations should apply only to "new" or essentially "new" land. This is in harmony with the policy on acreage limitation proposed by the IAWPRC in Committee Paper 29.)

6. Priorities

Other things being equal the rehabilitation of an existing reclamation enterprise should have priority over new enterprises.

7. Nonreimbursable Contributions

Any enterprise to which a loan is made under the program should be eligible to receive a Federal nonreimbursable contribution equal to the amount that would be considered nonreimbursable (because offset by benefits to the general public) were the Federal Government to undertake the work for which the loan is made in accordance with the Federal laws applicable at the time.

ATTACHMENT VII
To the First Report of the
Committee on Supplemental
Irrigation in Humid Areas
January 1952

WORK OUTLINE

FOR

A STUDY OF LEGAL PRINCIPLES RELATING TO

WATER RIGHTS IN THE EASTERN STATES

Foreword

The uncertainty which now exists with respect to rights to the use of water for irrigation in the Eastern States is due largely to the fact that the legal principles relating to such rights have been developed under the riparian doctrine. Under this doctrine each riparian owner along a stream has a right equivalent to that of every other riparian owner to make a reasonable use of the water of the stream for the purpose of irrigation. Thus, the right of a riparian owner to the continued use of water, instead of being fixed and definite as it is in the Western States which follow the appropriation doctrine, might vary widely even during the same season of the year. This fluctuation in the extent of the water right is a risk that must be considered by those who engage in irrigation in the Eastern States, and has undoubtedly had the effect of retarding the development of irrigation in these States.

Proposed Study

In order to determine whether it would be feasible to effect desirable modifications of the water rights of riparian owners in the Eastern States through legislation enacted under the State police power, and thereby to promote the development of supplemental irrigation, it is proposed that a detailed study be made of the court decisions and statutes relating to the water rights of riparian owners in six of these States. The six States would be selected with the view of providing representative study areas from the standpoint of climate and competing uses of water. It is believed that such a study would constitute a reasonably adequate basis for ascertaining the more significant legal problems relating to supplemental irrigation, and for determining from a legal standpoint whether such problems could be satisfactorily solved by the passage of suitable State legislation.

Financial Requirements

It is estimated that the proposed study could be completed within one year, at a cost of approximately $25,000.

Prepared by: The Office of the Solicitor

APPENDICES

TO THE FIRST REPORT OF THE

COMMITTEE ON SUPPLEMENTAL IRRIGATION IN HUMID AREAS

JANUARY 1952

Appendix A - Irrigation in Humid Areas.

Prepared for the Committee by the Soil Conservation Service.

Appendix B - Legal Principles Relating to Irrigation in the Eastern States.

Prepared for the Committee by the Office of the Solicitor.

UNITED STATES DEPARTMENT OF AGRICULTURE
Office of the Solicitor
Washington 25, D. C.

January 1952

LEGAL PRINCIPLES RELATING TO IRRIGATION IN THE EASTERN STATES

The growing importance of irrigation in the Eastern States during recent years has emphasized the need for further study of the legal principles governing the use of water for this purpose under the doctrine of riparian rights. In the present discussion of some of these principles, consideration will be given to the use of water for irrigation from three sources, namely, water in watercourses, ground water, and surface water. 1/ The question of the extent to which limitations may be imposed on vested water rights by state legislation will also be briefly considered.

Water in Watercourses

Definition. A watercourse has been defined as an inland stream of water which has a channel, consisting of a bed and banks, and which flows customarily in a definite direction or course for such a length of time as to give it a well-defined and substantial existence.

Nature and Extent of Right. Under the strict rules of common law, a riparian owner was entitled to have the stream flow to his land undiminished in quantity and unimpaired in quality, 2/ except for use by upper riparian owners for domestic purposes. However, under the modified doctrine of riparian rights which now prevails in the Eastern States it is uniformly held that the riparian right includes the right to make use of the water for the purpose of irrigation, among other purposes, and that such use is a property right which is entitled to protection to the same extent as property rights generally.

1/ The legal principles considered in this discussion are those that are generally applicable in the Eastern States, and are not intended to be determinative of questions concerning the legal status of water rights in any particular state. The determination of such questions would require a study of the statutes and decisions of the particular state, and their application to the facts in connection with which such questions arose.

2/ The right of riparian owners to the continued flow of the stream in its natural condition of purity is not considered in this discussion.

The right of a riparian owner which attaches to a watercourse is a right only to the use of the flow, and carries with it no ownership of the water itself. The right is an incident to the ownership of riparian land, and the acquisition of the right requires no other act than acquisition of the land. The right is usually applicable to the water of a lake, pond, slough, or any other natural body of water, as well as to the water of a running stream. The use of water for domestic purposes is, of course, entitled to a preference over its use for irrigation or other purposes.

The right of a riparian owner to use water for irrigation is a limited right which can be exercised only with a reasonable regard for the equal rights of other riparian owners. This does not mean that all owners are entitled to an equal quantity of water, but only that the right of each owner to make a reasonable use of the water is equivalent to that of every other owner. What constitutes a reasonable use of water for irrigation is largely dependent on the facts and circumstances of each case. For example, the amount of water which may be taken from a stream might depend upon such considerations as the size, situation and character of the stream, the extent of each ownership along the stream, the quantity of irrigable land owned by each owner, the amount of water needed to irrigate each acre of land, the minimum streamflow required for the protection of public health, the season of the year, the character of the soil, the aridity of the area, the character of the crops grown, the amount of water and the time required for irrigating each kind of crop, and all other matters affecting the question of a reasonable division of the water in case there should not be enough to meet the needs of all riparian owners. It seems clear that a lower riparian owner has no right to object to the use of water for irrigation by an upper owner unless he suffers material injury, even though he is put to a substantial inconvenience.

The amount of irrigable land belonging to the riparian owners, rather than the amount of land currently under cultivation, should be a controlling factor in determining their rights to the flow of a stream; otherwise, an adjustment would be necessary whenever an owner increased or decreased the area in cultivation. The measure of the rights of riparian owners does not depend solely on the lengths of their respective frontages on a stream. Many other matters need to be considered.

Land to Which Rights Attach. Generally, riparian rights to the use of water for irrigation apply only to riparian land; and in order for land to be riparian, it must be within the watershed and in actual contact with the stream or other body of water. In some cases it is held that riparian rights are applicable to land which abuts upon a stream or through which a stream flows, without regard to its extent or the manner in which the title was acquired. In other cases, however, it is held that riparian rights do not extend or attach to subsequent additions to the original tract. The distance to which the riparian owner's right to use of the water extends will depend upon the circumstances of each case. The only general rule that can be laid down is that both the distance and the use must be reasonable. Land within the watershed must not be so distant from the stream that the use of water thereon will be unreasonable in its effect upon the right of use of other riparian owners.

It is well settled that land lying in another watershed, although forming a portion of the same tract with riparian land, is not riparian in respect to the same stream. In other words, the riparian character of the land stops at the summit of the watershed. The fact that the land of a riparian owner lies above the level of the stream, and so cannot be irrigated except by the use of pumps and other equipment for raising the water, does not affect the right of the owner to use the water on such land.

Who May Exercise Rights. Generally speaking, riparian rights may be exercised only by riparian owners, and those who do not own or control riparian land cannot rightfully claim them. The person entitled to the use and possession of riparian land, although not the owner of the land in fee, is usually entitled to enjoy the riparian rights applicable to the land. Of course, riparian rights may not be exercised by a mere trespasser or intruder.

It is immaterial whether ownership of the land is vested in a natural or artificial person; in either case the ownership gives rise to riparian rights. The United States, the State and its subdivisions, or a private corporation, as the owners of riparian land, are entitled to the same rights that any other owners would have. While there are some decisions to the contrary, the weight of authority is that a municipality, like any other corporation, may exercise riparian rights only with respect to riparian land which it holds in a proprietary capacity, and that the riparian rights of its inhabitants are likewise limited to riparian land owned or controlled by them. The riparian right does not include the use of water from a stream to supply the inhabitants of a municipality with water for domestic purposes.

Diversion and Return of Water. A riparian owner has no right to go upon the land of another for the purpose of constructing a dam or a ditch to be used in diverting water for irrigating his own riparian land. He may acquire such right by grant, prescription, or estoppel. In the absence of such right, the point of diversion must necessarily be upon his own land. It has been held, however, that so long as a riparian owner takes only his reasonable share of water for irrigation, and uses it upon his riparian land without unreasonable waste, other owners below have no right to inquire how, or by what means, or at what place he manages to divert his share from the stream. There is no objection to changing the place of diversion if others are not injured thereby

It is the general rule that the owner making the diversion must return the surplus water to the channel before it leaves his land. Conditions may exist, however, such as the need to obtain an adequate fall, which makes it imperative for an owner to divert water at a point above his land or to return the surplus water at a point below his land. In such event, he may secure the necessary easement in one of the ways mentioned above. It should be noted that the question of whether an owner diverts water at a point above his land or discharges it at a point below his land may have an important bearing in determining whether the use is reasonable. The conveyance of water in ditches necessarily involves loss by absorption and evaporation, and since a riparian owner is entitled only to a limited quantity of water, it appears that where he conveys water in ditches across the land of others for his own convenience, the loss should properly fall on him.

Right to Detain Water. It is fundamental that a riparian owner has the right to detain the water of a stream temporarily by means of a dam for the purpose of irrigation, provided that in so doing he does not injure the land of other owners or unreasonably interfere with their right to the use of the water. Whether the detention of the water is reasonable depends upon the facts of each particular case, and in making a determination thereof consideration may be given to the extent, duration, and necessity for the use of the water for irrigation purposes; the size and capacity of the stream and the uses to which it is subservient; the general usages or customs with respect to the same or similar streams; and the needs of the various riparian owners. The fact that the construction of the dam causes a slight disturbance of the current or loss of water by evaporation does not make the detention unreasonable. However, the construction of the dam will be held unlawful if it causes substantial injury to other owners on the stream, either by interfering with their rights to the use of the water or by flooding their lands upstream or downstream. The owner of a dam is bound to exercise ordinary care not only in its construction but also in its operation and maintenance, and will, of course, be liable for any injuries caused by his negligence in regard thereto.

Prescriptive Rights. Since the riparian right is not dependent on the use of water, the right is not lost by non-use alone. It may be lost, however, by adverse use on the part of others. Generally, a prescriptive right to the use of water can be acquired only by an adverse use of the character required for the acquisition of title to land. The use must be continuous, uninterrupted, notorious, and adverse under a claim of right for the prescriptive period. The nature of the use to which the water is put by one claiming a right of use by prescription is immaterial so far as the validity of his title is concerned.

Unless the use of the water is adverse for the prescriptive period, it will not be sufficient to confer a valid prescriptive title. In order to be adverse, the use must be an invasion of the rights of the person against whom it is asserted, of such a character as to afford him grounds for bringing action against the person claiming the right of use. A use can never be adverse if it is by permission of the owner since he cannot bring an action for acts which he expressly sanctions. A mere license to divert a stream cannot be ripened into a right by lapse of time.

Whether a use of water is adverse to a riparian owner depends on whether the use is an infringement of his rights. Generally, if the use relied on is the lawful exercise of a riparian right, it cannot be regarded as so adverse as to constitute the basis of a prescriptive right. If, on the other hand, the use is a wrongful or improper one, it may satisfy the requirement as to adverseness. After water passes the land of a riparian owner, he has no further right to its use, and is not required to take any action to prevent the accrual of a prescriptive right. Thus, a lower riparian owner cannot acquire by prescription the right to the full flow of a stream as against the right of an upper owner to make a lawful use of the water.

A different rule applies, however, where the use of the water is made before it reaches the land of a riparian owner. Thus, the impounding of the natural flow of a stream in order to insure a uniform flow in time of drought, not being a lawful exercise of a riparian right, may form the basis of a prescriptive right to be asserted against lower riparian owners. If damage is actually caused by a diversion, a prescriptive right may undoubtedly be created. If the diversion is restricted to times in which there is an adequate supply of water, or if not so restricted, and there is left in the stream a sufficient amount of water to meet the needs of every riparian owner, no injury exists for which an action may be brought. Thus, the diversion of a large amount of water when there is an abundant supply does not give a prescriptive right to divert the entire flow during dry seasons.

Transfer of Rights. Riparian rights, like other property, may be transferred by grant. Such rights pass with the transfer of riparian land without any designation in the conveyance. The rights are regarded as being annexed to the soil, and pass with a conveyance of the land not as an easement or appurtenance, but as part and parcel of it. Despite the fact that riparian rights are annexed to the soil, as incidents thereto, they may nevertheless be severed by specific language from the ownership of the land by a grant of such rights to another or a reservation thereof in the conveyance of the land, or by condemnation or prescription. The view has been expressed that the rule permitting severance of riparian rights from the ownership of the land is subject to some limitations and exceptions, and that public policy may require certain rights to remain vested in the owner of riparian land.

A riparian owner has the right to contract for the use of his proportionate share of water on riparian land. As against himself, or his grantee, a riparian owner may also contract for the diversion and use of water on non-riparian land, although such contract will not affect the rights of other riparian owners.

Ground Water

Definition. For the purposes of this discussion, ground water is regarded as either percolating or flowing. The former consists of water percolating through the earth or flowing in undefined underground channels, and the latter of water flowing in defined subterranean streams.

Percolating Water. All ground water is presumed to be percolating water, until it is shown that it flows in a known and defined channel; and the person who claims rights in an underground stream has the burden of proving its existence.

The two doctrines governing the use of percolating water are known as the common-law or English rule, and the rule of reasonable use or American rule. Although the common-law rule originally prevailed in all of the Eastern States, and still obtains in a number of them, the general trend of recent decisions is toward modification of this rule and adoption of the rule of reasonable use.

Under the common-law rule, percolating water is regarded as being a part of the freehold, and the landowner has the free and absolute right to use it in any manner that he chooses. Such water is considered to be the exclusive property of the owner of the surface of the soil, and subject to barter and sale as any other property.

It is held in some cases that under the common-law rule the motive with which a landowner abstracts percolating water from the soil is immaterial. These decisions are based on the promise that if there is an absolute right to remove the water, the motive with which it is done is unimportant. The majority view, however, is that the abstraction of water by a landowner, for the malicious purpose of causing injury to another, gives the injured person a right of action. It is also held under the common-law rule that a landowner has no right to extract percolating water merely for the purpose of wasting it.

The rule of reasonable use came into existence largely as a result of inequities caused by unreasonable withdrawal of water from a common underground supply, to the injury of a landowner who had been making a beneficial use of the water. The rule is based on the principle that a landowner is entitled only to a reasonable, and not an absolute and unqualified, use of percolating water. The rule is aptly expressed by the maxim that one must so use his own as not to injure another. Some courts regard it as being more of a qualification of the common-law rule than the establishment of a new rule.

The rule of reasonable use has been most often applied in cases in which percolating water was being extracted for the purpose of sale at a distance, for municipal water supply, or for irrigating land other than that from which the water was extracted. These were held to be unauthorized uses where they interferred with a reasonable use of the water by other landowners. The rule does not prevent a reasonable use of percolating water for the purpose of irrigating the overlying land. The extent of the right of use for irrigation depends upon the facts and circumstances involved in each case and must be determined in relation to the similar rights of other owners of land overlying the same general underground source of supply.

The rule of reasonable use is often referred to as the rule of correlative rights, and the phrases "reasonable use" and "correlative rights" are frequently used interchangeably. Under the correlative rights doctrine, the owners of overlying land have coequal or correlative rights to the ground water supply for use on such land; and one landowner is not entitled to extract more than his equitable share of the water even for use on his own land if the rights of other owners are injured thereby.

Subterranean Streams. There is a distinction between rights to the use of water which percolates through the soil and that which flows in defined subterranean streams. The same rules of law applicable to surface streams are generally applied, where practicable, to water flowing in defined subsurface channels. Thus, a landowner having riparian rights in an underground stream may make a reasonable use of the water of the stream even though its volume is thereby diminished. He has no right, however, to divert,

waste, or pollute the water to the injury of other riparian owners. His right to make a reasonable use of the underground water for the purpose of irrigation is governed by the same general rules of law that apply to the use of water in surface streams for this purpose under the doctrine of riparian rights.

Springs and Wells. The owner of land on which a spring rises which forms the source of a watercourse, has only the rights of a riparian owner to the use of water from the spring. However, if a spring does not constitute the source of a watercourse which flows from the land on which the spring rises, the spring is ordinarily regarded as the exclusive property of the owner of the land on which it is situated.

A landowner may improve a spring situated on his own land by digging, cleaning out, curbing, and walling it up, provided he does not change the natural course of the flow of the water, and makes no change which injures the rights of other owners. Any resultant increase in the flow of the spring will inure to the benefit of the landowner who made the improvement.

Rights to the use of water from wells for the purpose of irrigation depend in the first instance on whether the underground water flows in a defined channel, and if it does not, on whether the common-law rule or the rule of reasonable use in regard to percolating ground water is applicable. If the well is supplied from an underground stream flowing in a defined channel, the doctrine of riparian rights applies, and the owner may make only a reasonable use permitted a riparian owner under that doctrine. If the source of the well is percolating water, the owner has the right under the common-law rule to make whatever use of the water he pleases, while under the rule of reasonable use, he is entitled only to a reasonable share of the water.

Surface Water

Definition. Water which in its natural state is flowing vagrantly over the surface of the ground, or standing in bogs or marshes, regardless of its source, is classified as surface water. When surface water reaches and becomes part of a watercourse, or a lake, pond, or other definite body of water, it loses its character as surface water and is subject to the rules applicable to watercourses.

Ownership and Use. Generally, a landowner has an absolute right to all surface water upon his land, and he may, for the purpose of irrigating his land, capture and utilize such water and prevent it from flowing upon the adjoining land of a lower owner. The lower owner cannot acquire a right by prescription to have the water continue to flow upon his land.

The right of an upper owner to retain and apply all his surface water to his own use has been qualified in some cases by restricting it to a reasonable use of the water on his own land. In other cases it has been held that the upper owner may not use the water primarily for the purpose of depriving another of the benefit of using it.

There are two distinct rules in regard to the right of a lower landowner to obstruct and divert the surface water flowing from the land of an upper owner. One rule is known as the civil-law rule, and the other as the common-law or common enemy rule. Under the civil-law rule, the upper owner has an easement to have surface water flow naturally from his land upon the land of the lower owner. Under the common-law rule, no such easement exists in favor of the upper owner, and the lower owner has the right to obstruct the flow of surface water or divert it from his land without incurring any liability to the upper owner by reason of such obstruction or diversion. The civil law rule has been qualified in some cases to the extent of permitting a lower owner to interfere with the natural flow of surface water whenever such action is reasonably necessary for the protection of his property. The modified rule is based on the maxim that one must so use his property as not unnecessarily to injure others.

There is no distinction between the civil-law rule and the common-law rule in regard to the right of a landowner to use surface water found upon his land: Under either rule, an owner is entitled to capture surface water which flows upon his land and use it for the purpose of irrigation.

After surface water has been captured and reduced to physical possession, it becomes personal property and may be used in any manner that is consistent with the public safety and that does not damage the property of others. Since the rules governing watercourses are not applicable to surface water, there is no legal objection to the use of the water on land other than that on which it is captured.

There are no limitations in the law of water rights in regard to the type of structure which a landowner may use in capturing or impounding surface water. He may reduce it to possession in any manner he chooses so long as he does not create a nuisance or cause injury to others in so doing.

The construction of dams exceeding specified heights or impounding water in excess of specified quantities usually is regulated by state statutes. These statutes generally provide that dams to which they are applicable may be constructed only after approval by appropriate officials and issuance of construction permits. The purpose of these statutes is to protect the public against the hazards that would result from improper construction of impounding dams. The statutes do not affect the right of a landowner to retain and apply all of his surface water to his own use.

In many cases where surface water is impounded, it is necessary to make provision for drainage of the unused water. It is a general rule of law relating to the drainage of surface water that an upper owner is not authorized to increase materially the quantity or volume of surface water discharged upon the adjoining lower land. Thus, a landowner who has impounded surface water for the purpose of irrigation is not ordinarily entitled to discharge the excess water upon the land of a lower owner in greater volume or in more concentrated flow than would have resulted if

natural conditions had been left undisturbed. Neither the civil-law rule nor the common-law rule gives the upper owner the right to cast surface water in a body on the adjoining lower land in such manner as to cause injury to the lower owner.

Limitation of Water Rights by State Legislation

The foregoing discussion of legal principles indicates some of the reasons for the uncertainty and indefiniteness presently surrounding rights to the use of water for irrigation in the Eastern States, and emphasizes the need for making suitable changes in existing state laws if the development of irrigation in these states is not to be seriously impeded. Attention will be given, therefore, to the position taken by the courts in regard to the validity of state statutes which have been enacted for the purpose of regulating the exercise of water rights.

It is well established that rights to the use of water constitute property rights which may not be taken except for public use, and upon the payment of just compensation. Thus, a state does not have the power to adopt legislation which will have the effect of destroying vested water rights. In applying this principle, the courts have declared statutes of some of the Western States void which (a) denied to riparian owners the right to a continued natural flow of the stream, (b) limited the use of water during any one year for irrigating riparian land to a specified quantity per acre, (c) declared that all water within the state should belong to the public and be subject to prior appropriation, and (d) provided that riparian rights to the use of water should be lost by nonuse alone. These and other similar statutes of these states were held to be violative of constitutional provisions prohibiting the destruction of vested water rights.

While a state may not destroy vested water rights, it has power to impose reasonable restrictions upon the enjoyment of such rights through legislation enacted under the state police power. The question of the validity of any such legislation will depend upon whether it is a proper exercise of the police power, and that, in turn, will depend upon whether the purposes sought to be accomplished by the legislation are sufficiently related to the promotion of the general public welfare.

Statutes of both Eastern and Western States which were enacted for the purpose of securing a proper regulation and supervision of vested water rights for the public good have been upheld by the courts as a valid exercise of the state police power. State statutes have been sustained on this ground which (a) provided that the right of a riparian owner to the continuous flow of a stream should be limited to such flow as is necessary to preserve the beneficial uses to which he is already applying the water, (b) regulated, in accordance with adjudicated priorities of water rights, the headgates controlling the diversion of water under such rights, (c) made it unlawful to transport water within the state to a point outside the state, and (d) prohibited bathing in a stream tributary

to a reservoir from which a municipal water supply was obtained. It was held that the limitations provided for in these statutes were a reasonable exercise of the police power and did not constitute a deprivation of vested rights. It should be observed, however, that in the Western States in which the greater number of cases of this type have arisen, the general trend of court decisions for many years past has been to place increasing restrictions on riparian rights, and thereby to enlarge the opportunities for development of irrigation under the doctrine of prior appropriation.

The extent to which interference with vested riparian rights in the Eastern States would be sustained by the courts as a proper exercise of the state police power would depend upon the facts in connection with the enactment of the particular legislation. It seems reasonable to assume that at the present time the degree to which such interference would be approved would be materially less than that permitted in the Western States where the problem of water supply is much more acute and where far greater departures have been made from common-law concepts of riparian rights. It would not be possible, therefore, to determine in advance the question as to whether an Eastern State, in adopting suitable legislation for the regulation of water rights, could do so without coming in conflict with constitutional provisions prohibiting the taking of private property without due process of law. The final answer to this question will not be known until such legislation has been enacted and its validity has been considered and passed upon by the courts.

Bibliography

Farnham, H. P., The Law of Waters and Water Rights, 1904.

Wiel, S. C., Water Rights in the Western States, 2nd ed., 1908.

Long, J. R., A Treatise on the Law of Irrigation, 1902.

Thompson, D. G. and Fiedler, A. G., Some Problems Relating to Legal Control of Use of Ground Waters, Jour. Amer. Water Works Assn., July, 1938.

Hutchins, W. A., Selected Problems in the Law of Water Rights in the West, 1942.

67 C. J., Waters

30 Am. Jur., Irrigation

56 Am. Jur., Waters

55 A.L.R. 1385-1566; 109 A.L.R.395-422, Anno., Subterranean or Percolating Waters.

56 A.L.R. 277-303 Anno., Constitutionality of Statutes Affecting Riparian Rights.

70 A.L.R. 220-241, Anno., Extent of Detention or Retardation of Water Incident to Riparian Rights.

85 A.L.R. 465-471, Anno., Constitutionality of Statutes Relating to Surface Water.

Bingham, J. W., Some Suggestions Concerning the California Law of Riparian Rights, California Law Review, Vol. 22, p. 251, March 1934.

Constitutional Law - Conservation of Waters - Validity of Statute Limiting Riparian Rights. Michigan Law Review, Vol. 34, p. 274, 1935.

Treadwell, E. F., Developing a New Philosophy of Water Rights, 38 California Law Review, Vol. 38, p. 572, Oct. 1950.

Bennett, John K., Some Uncertainties in the Law of Water Rights, 21 Southern California Law Review, Vol. 21, p. 344, July 1948.

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IRRIGATION IN HUMID AREAS

Soil Conservation Service
November 1951

History and Growth

Irrigation in humid areas of the United States has increased nearly three-fold during the past 10 years. Humid areas are generally considered to include all land lying east of the 97th meridian plus the coastal area of northern California and of western Oregon and Washington. Irrigation in arid and semi-arid areas of the country has been practiced as a matter of necessity ever since the first agricultural settlements were made in these areas. But even in humid areas, where rainfall is generally considered adequate and in some instances excessive, there are from time to time crucial periods during which soil moisture is insufficient for optimum plant growth.

For generations certain crops which required ground saturation or actual inundation, such as rice, cranberries and watercress, have been irrigated in humid areas. The feasibility of irrigating still other crops has been recognized for many years. Research investigations have been carried out by the Department of Agriculture in cooperation with State experiment stations, particularly in New Jersey, Wisconsin and Florida since 1900. Only within the past decade or so, however, have we come to realize the full potentialities and economic advantages of humid area irrigation. From 1940 to 1950 land under irrigation in humid areas of the United States has increased from approximately 300,000 acres to approximately 800,000 acres, not including the ricelands of coastal areas which embrace approximately 1,600,000 acres in Louisiana, Arkansas, and eastern Texas. At present, irrigation is being increasingly used in humid areas for fruits, intensively-grown shallow-rooted crops, such as vegetables, berries and flowers, and for high-producing pastures and other forage and field crops where temporary shortage of water sometimes critically depresses yields. Humid area irrigation is steadily becoming a more important factor in the conservation and use of land and water resources.

Present Status

Irrigation in humid areas is now reported in 38 states and in 752 counties. Preliminary data on irrigation by states in 1940 and 1950, and the amount supplied by sprinklers, based on U. S. Bureau of Census data, are shown in Table 1. The largest acreage irrigated outside of rice-growing sections is in Florida. In 1950 approximately 350,000 acres were under irrigation in 67 counties in this State. Supplemental water is being applied principally for vegetable, citrus and flower production. The area irrigated in Florida in 10 years has nearly tripled. Other humid-area States in which substantial acreages were irrigated in 1950 included Massachusetts, with 16,695 acres; New Jersey, with 26,276 acres; Connecticut, with 8,088 acres; South Carolina, with 6,408 acres; Michigan, with 13,902 acres; and Wisconsin, with 9,802 acres. In humid areas of California, Oregon and Washington, a total of

Table 1 - IRRIGATION IN HUMID AREAS
(Rice lands not included)

	Land irrig. 1940 acres	Land irrig. 1950 acres	Land irrig. by sprinklers 1950 acres	No. of counties reporting 1950	SCS technical assistance: Fiscal year 1951 acres	SCS technical assistance: Accumulative t 6/30/5 acres
Connecticut	520	8,088	7,669	8	16	606
Delaware	7	404	404	3	0	120
Maine	143	2,299	2,230	14	1,656	2,000
Maryland	67	722	268	12	648	807
Massachusetts	2,049	16,695	6,706	13	886	1,437
New Hampshire	25	622	556	6	628	1,050
New Jersey	7,956	26,276	18,124	21	232	400
New York	5,948	3,156	2,675	19	176	2,030
Pennsylvania	3,356	#	#	#	0	705
Rhode Island	109	1,559	1,462	5	0	600
Vermont	0	303	259	7	0	199
West Virginia	270	65	14	9	62	100
Region I	20,450	60,189	40,367	117	4,304	10,054
Alabama	281	195	188	14	117	298
Florida	126,191	350,000	#	67	14,274	110,609
Georgia	158	#	#	#	2,401	6,548
Kentucky	205	488	346	18	53	78
Mississippi	94	4,379	177	18	1,375	1,462
North Carolina	246	1,936	1,776	30	344	1,340
South Carolina	411	6,408	1,793	24	1,162	5,489
Tennessee	311	1,022	981	22	0	127
Virginia	687	2,863	2,758	18	1,307	3,635
Region II	128,584	367,291	8,019	211	21,033	129,586
Illinois	307	#	#	#	80	80
Indiana	685	#	#	#	70	250
Iowa	2,258	881	713	19	145	391
Michigan	2,960	13,902	11,894	68	103	1,174
Minnesota	2,968	4,235	2,097	35	0	0
Ohio	4,536	#	#	#	0	0
Wisconsin	2,345	9,802	7,513	55	0	0
Missouri	960	1,648	749	22	80	80
Region III	17,019	30,468	22,966	199	478	1,975
Arkansas	)	) 1/	)	24	)	)
Louisiana	) 50,000	) 132,800	) 8,240	12	) 3,900	)13,956
Oklahoma	)	)	)	11	)	)
Texas	)	)	)	12	)	)
Region IV	50,000	132,800	8,240	59	3,000	13,956
Kansas	745	775	176	13	0	106
Nebraska	3,010	2,136	71	9	601	791
Region V	3,755	2,911	247	22	601	897
California	30,524	26,400	10,600	9	3,908	7,986
Oregon	33,303	94,800	71,300	16	2,443	5,581
Washington	15,131	33,800	19,500	19	1,580	4,399
Region VII	78,958	155,000	101,400	44	7,931	17,966
		# 50,000	# 200,000	# 100		
U.S.Totals	298,766	798,659	381,239	752	37,347	177,689

Estimated total for states where census data are not yet available.

1/ Includes 90,000 acres pasture irrigation on rice land.

approximately 155,000 acres was under irrigation, primarily for improved pastures, truck crops, and special crops grown for seed. The present status of irrigation by states is shown in Appendix 1.

Factors Favoring Development of Humid Area Irrigation

Seasonal moisture deficiencies occur in most parts of the humid areas of the United States. Droughts, even in the higher rainfall belt of the eastern seaboard, have been recognized as a farming hazard causing partial crop failures from once to several times in every decade. Farmers have fully realized that if soil moisture supply could only be supplemented during periods of deficiency, crop yields could be greatly increased and the land could be used more nearly up to its full productive capability.

The rapid increase in irrigated acreage during the last 10 years has resulted from a number of factors, including: (a) Improved margins of profit from many crops and pasture forage, which has made possible substantial capital outlays for irrigation devlopment; (b) improved transportation and marketing facilities such as deep freezing and rapid shipment by truck, which has made it possible to supply urban centers with more certainty of adequate return on capital investment; (c) improved irrigation equipment, particularly the portable sprinkler types; (d) availability of electricity in many rural areas; (e) better understanding of irrigation potentialities brought about by educational processes; (f) provision by the Federal Government of expert technical services to assist farmers in planning and installing irrigation facilities; (g) financial assistance through credit and direct aids by the Federal Government; and (h) Federal and State research.

Improved economic returns

Increased economic returns from crop protection in recent years have encouraged the trend toward irrigation. When farmers can sell their crops at good prices it pays to irrigate, as well as to follow other practices that assure any marked increase in yields. Increased income derived from one or two truck crops has sometimes more than paid for the cost of an irrigation system. Irrigation of truck crops permits a farmer to time his farming operations so as to have his crop ready to meet the most profitable markets. For example, he can irrigate a dry field and after a day or two plant young cabbage or other crops and quickly get a good stand-- in timely adjustment with market prospects. Irrigation can thus be employed at will to meet the exigencies of drought.

Irrigation of pastures has also been of growing importance. Farmers need green pastures during all the growing season. Conservation pasture practice not only calls for the most adaptable grasses and legumes and good all-round pasture management, including fertilizers, but for timely irrigation also. In the Pacific Coast States, the Soil Conservation Service finds that around 600 pounds of beef are produced on good irrigated pastures as against gains that seldom exceed 250 pounds per acre on dry pastures. Dairy farmers have found that irrigated pastures enable cows to give more milk during summer dry spells. Many farmers in soil conservation districts have found that irrigation of pastures more than pays for itself.

Improved irrigation equipment

Development of practical and efficient portable sprinkler systems has been a major stimulus to irrigation in humid areas. Such systems are well suited to irregular topography not normally irrigable by gravity methods. They are easi removed from fields to facilitate farming operations. They also fit into conservation farming by permitting proper crop rotations and contouring practices

An increasing number of commercial firms handling sprinkler equipment are doin a good job of designing improved mechanical features. Such designing covers adaptation of pumps and engines to different conditions, sizes of pipes, pipe fixtures, and sprinkler heads.

The manufacturers and distributors of sprinkler equipment have had a major rol in promoting supplemental irrigation in humid areas. Nearly half of the total area reported under irrigation in 1950 was supplied by the sprinkler systems.

Technical assistance

Provision by the Federal Government of skilled technical assistance from the Soil Conservation Service, through soil conservation districts to landowners and operators, has been a major factor in the increase in humid area irrigatio The Service is regularly assisting landowners and operators with the "know-how on irrigation in every state and nearly every county where irrigation is practicable as a part of its regular soil and water conservation program. During the fiscal year 1951, the SCS assisted with the establishment of over 37,000 acres of new irrigation in humid areas. During the past decade it has provide technical assistance to landowners and operators on about 22 percent of all th land now irrigated in humid areas. The greater part of this assistance has be given since 1945. In the Northeast about one-sixth and in the Southeast about one-third of all land put under irrigation has received such technical assista

Research

The Department of Agriculture in cooperation with the States has been conducti research in supplemental irrigation in humid areas since 1900. Since 1939, wh Departmental research in this field was transferred to the Soil Conservation Service, the Research Division of Drainage and Water Control has carried out a substantial number of project investigations. It now has 16 research projec underway in 15 states and Puerto Rico on various problems in this field. The details of this research are described in Appendix 2.

Relation of Irrigation to Land and Water Resources

Irrigation in humid areas is intimately related to the development, use and conservation of all land and water resources. The President's Water Resources Policy Commission has pointed out clearly why land and water management cannot be disassociated, in planning for the watershed and problem area, the district or county, or the farm and even each field of the farm. For example, if the best use of both soil and water resources is to be achieved, they must be kept

in the best possible balance throughout the season of plant growth. Obviously the soil conservationist must try to provide for the optimum storage of moisture in the soil from natural precipitation and for the safe disposal of excess water.

Irrigation in humid areas cannot be considered independently of other land and water problems. The substantial quantities of water required for this purpose must be considered in terms of total available water supply, including other such essential uses as domestic and municipal supplies and waterflow needed for power, navigation, pollution abatement, fish and wildlife, recreation, and related purposes. The practicability of irrigation must be considered in connection with land capability, drought hazards, availability of markets, cost of equipment, credit facilities, and alsmot all other factors affecting agricultural programs.

The farmers' need for technical assistance

Need for expert technical assistance becomes evident from the simple questions of the farmer who is considering irrigation. He may ask, for instance, "How often will I need to irrigate?" Lacking technical help, equipment salesmen and farmers have often used rules of thumb for timing the amount and frequency of irrigation applications in humid areas. Several of these rules of thumb are: "An inch in an hour," "Don't irrigate until the crop shows signs of needing water," and "Don't irrigate today, it may rain tomorrow." Most of the records on humid area irrigation have been recorded where one of the above rules was used to determine the time, rate, and frequency of applications. As a result, many false conclusions have been drawn as to the potential crop yields from irrigation if the right amount of water had been applied at the right time for the particular soil to meet the particular crop needs.

Trained technicians are needed to help farmers, individual and in groups, on their farms and in their communities with their individual and group irrigation problems, whether in high or low rainfall areas. Climatic records need to be analyzed to determine the probabilities of soil moisture deficiencies and drought occurrence. Optimum requirements of crops for moisture should be known. Moisture-holding capacity of various soils has to be considered. The time, rate, and amount of water application are extremely important factors in efficient and profitable irrigation. The farmer must know the capabilities of his land. He must know not only how much water supply he can count on, but how much water he will need for any given amount of irrigation of particular crops under particular drought conditions.

Nature of assistance provided by the Soil Conservation Service

The Soil Conservation Service is providing through soil conservation districts the kind of technical assistance needed by thousands of irrigation farmers. Trained technicians are assigned to the more important locations with respect to irrigation problems, in keeping with available manpower and other facilities. In addition to assisting farmers with their irrigation problems one of the more important jobs of these specialists is to train other technicians so that assistance of the required standards may be provided for the rapidly increasing number of farmers interested in irrigation.

Individually and in cooperation with the Extension Service, the Soil Conservati Service is holding training meetings for farmers, equipment salesmen, and repre sentatives of other agricultural agencies to extend their knowledge of irrigati methods and equipment in order to provide the greatest amount of service to all farmers who are interested in purchasing, installing, and operating irrigation systems in humid areas.

On-the-farm technical assistance provided by the Soil Conservation Service has, in the main, consisted of design and layout of farm irrigation systems. This often involves adapting the systems generally available through commercial channels to the particular requirements of the farm enterprise and to the physical conditions of the land, water supplies, and cropping needs of each farm. The Service has worked closely with irrigation equipment manufacturers, with State experiment stations in obtaining research information, and with various organizations interested in the conservation and development of land and water resources.

After installation the Service helps the farmer with initial operation of the system. It trains the irrigator to determine the upper and lower limits of available soil moisture by simple methods so that he will know when to begin applying water before the lower limit or wilting points has been reached and when to discontinue the application before runoff, water logging, or deep percolation causes unnecessary losses or damage. The Service technicians help him to determine the rate at which to apply water through a gravity system or the required pressure to maintain in the sprinkler system and the duration of application at optimum rates.

Determination of physical land conditions on each farm is considered by the Service a prerequisite to planning an irrigation system. The system is planned in the light of land capability based on the principle of using each acre in accordance with its capability and treating each acre in accordance with its needs. Supplemental irrigation is considered as one of the normal aspects of planning carried out with the farmer to provide him a sound technical basis for carrying on his farm operations in accordance with conservation principles.

The Service has been able to bring to bear on the needs of irrigation farmers in humid areas a vast amount of experience obtained through its nationwide organization in assisting farmers in the arid West where irrigation has been practiced for more than a century. While physical conditions differ markedly, much information obtained in the West can be adapted to eastern conditions. For example, although the rate of consumptive use by different crops has not been widely studied in the East, it has been possible to draw upon information developed in the West and to modify it so as to make it adaptable to meeting the needs of irrigators in the humid states. The methods developed by Blaney and Criddle of the Soil Conservation Service Research Division for "Determining water requirements in irrigated areas from climatological and irrigation data," SCS-TP-96, August 1950, have been used.

Complex technical problems associated with irrigation

Severe erosion, water logging, increased alkali accumulations, wasted water and fertilizer often result from applying water at excessive rates or in excessive amounts. In the humid areas, water application should usually be stopped some

short of the moisture-holding capacity of the soil to allow some storage space for rain that may occur shortly after irrigation. Intense rains immediately following irrigation have been known to cause severe erosion on recently irrigated but unprotected fields.

Surface puddling or sealing of the soil frequently results from the impact of water from sprinklers if the soil surface is unprotected. Protection against such sealing effect is important to prevent erosion. This difficulty requires the selection and use of properly designed nozzles so that the drop size will produce little or no puddling. Even if nozzles are properly adjusted, actual operation of the system with pressures either above or below the design rate may adversely affect both the size of drop and the splash action.

Where channel and furrow irrigation is used instead of sprinkler irrigation the length and gradient of furrows must be adjusted to soil characteristics, slopes, and the available quantity of water. If excessively long furrows are used, severe erosion frequently occurs. It is almost impossible to obtain uniform distribution of moisture throughout the length of the furrow if it is too long. Excessively steep furrows cause high rates of erosion as well as uneven distribution of moisture. Where land leveling is practicable, it must be done under expert technical supervision to avoid the harmful effects of uncovering subsoil during the leveling operations. The field distribution system must be laid out with proper gradients to accomplish efficient water distribution.

Complex technical problems are associated with irrigation in any area. It is not sufficient to know merely the total needs of the crop for water, but it is necessary to know the difference between the amount of moisture available from precipitation and the amount required for optimum plant growth. One of the first steps in the design of an irrigation system, therefore, is to determine the frequency and extent of likely soil moisture deficiencies on the fields involved. This requires an evaluation, both of rainfall records and of soil and other physical characteristics in the fields. Such determinations are a prerequisite to adequately estimating the amount of water required and of the needed capacity of the irrigation system which must be designed. The frequency of moisture deficiencies must be determined in such a manner that they can be compared directly with week to week demand for moisture by different crops.

In order to estimate the total amount of water that must be provided, the total number of irrigations per month and per season, and their probable volume under the most unfavorable climatic conditions, must be calculated. This requires an estimation of the consumptive use rate and the amount of water available to plants that can be held by a given soil from the natural rainfall that would be expected under such conditions. The efficiency of an irrigation system is often determined by its ability to meet the greatest need.

Methods of irrigation

The method of applying water to the land is also important if high efficiency is to be obtained. The method of application should provide for the most uniform distribution with the least waste of water, the minimum leaching of

fertilizer, the least erosion of soil, and the lowest cost. The cost of application is extremely important in supplemental irrigation because the increased yields must be sufficient to more than offset the cost.

Generally, the method of water application will depend primarily on the soil characteristics, particularly its permeability, the use of the land, the surface topography, and the amount of water available. If the area is relatively flat, the infiltration rates are average, and adequate water is available, it is possible that surface irrigation will be preferable to any other form. If the surface is slightly uneven and the soil deep, it may be practicable to level the land to prepare it for surface irrigation. If the land is rolling or if it is highly permeable, it may be desirable to use sprinklers. In many eastern areas the topography is not adaptable to surface irrigation without excessive cost for land leveling. Trained technicians take all these factors into account in making recommendations to the farmer that will give him the most efficient system for his particular conditions at the least cost.

Still other practical considerations must be taken into account. A series of wet years may occur when no supplemental irrigation is needed. Experience indicates that under such conditions surface systems often are allowed to deteriorate to the degree that they are not useful when a dry period occurs. If a sprinkler system is available for the farm it can be placed in use within a reasonable time. The portable sprinkler also has the advantage of being adaptable to irrigated rotated crops on different fields from a central water supply system. On the other hand, the cost of power and the cost needed for moving the pipe make the operation of portable sprinklers expensive. These costs must be taken into account when a recommendation is made of the type of system or method of application to be used.

Water supply

In the past, supplemental irrigation has been largely an individual farm undertaking. That is, the water needs and supply were usually determined in relation to an individual farm, rather than in terms of needs of other users in the watershed, such as other irrigators, municipalities, and industries. Future expansion of supplemental irrigation will depend to a considerable extent upon the total water supply available for all beneficial uses. This supply must be considered in terms of an entire watershed or water problem area and not just in terms of individual farms. A definite need exists already in some humid areas for the development of community-type water supplies. With this in mind, the potentialities of supplementing the present water supplies for irrigation through storage in reservoirs designed primarily for power, flood control or other purposes, should be given more consideration.

One of the first steps in planning for irrigation, whether it is for a single farm or for a larger area is to determine the water needs. These needs should be defined in terms of quality as well as quantity. After this determination has been made, the next step is to locate a supply of water adequate in quantity and satisfactory in quality.

The sources of water supply for supplemental irrigation are surface water in streams, drainage ditches, ponds and storage reservoirs, and groundwater from wells, interception galleries, and springs. Each source of supply should be checked thoroughly for quality and quantity.

Water for irrigation does not have to be as pure as rain water. In fact, many supplies, especially surface streams, contain salts, organic matter, and mineral nutrients, which are beneficial to soils and to plant growth. However, water draining from alkali or salty lands, pumped from below sea level, or contaminated by industrial effluents may contain excessive amounts of alkalies, oils, and other substances, which may make it unsuitable for irrigation. Such contamination can be discovered and measured by physical and chemical analysis. Consideration should be given also to possible future pollution of water supplies from agricultural or industrial developments in the watershed. When water is to be pumped from wells in coastal regions, a careful appraisal should be made of the probability of the groundwater table being lowered to such an extent that salt water will intrude.

Streamflow is the major source of supply for supplemental irrigation in humid areas, especially in the northeastern states, in western Oregon and Washington, and in a few of the midwestern States. Where drainage water is available, it is often used to supplement water from streams. The dry weather flow of many streams and drainage ditches is inadequate. In such cases provision must be made for surface storage. Along the Atlantic coastal area many of the tidal inlets are used for storage. In upland areas natural lakes and farm ponds are the principal sources of surface water. Natural lakes are generally the source of supply in the Lake States, such as Maine, Michigan, Minnesota, Ohio, and Wisconsin, and in the central peninsula of Florida. The principal areas in which groundwater is available are along the Atlantic and Gulf of Mexico coastal plains and in the bottomlands along the principal rivers and their major tributaries.

In many sections of the humid areas there are serious shortages of water during crop growing seasons. On only a few farms are there streams, ponds, or wells that are sufficiently reliable to supply water when it is needed. This does not mean there is insufficient annual rainfall. On the contrary, many streams carry millions of acre-feet of water into the oceans each year. At the time of greatest supply, however, demand is usually at its lowest point. Conversely, when the supply is at its lowest point, and in many instances nonexistent, the demand is greatest. This is particularly true for surface supplies. These seasonal shortages of supply are major factors in retarding the expansion of supplemental irrigation.

Landowners and operators recognize the necessity of providing water supplies to meet seasonal demands. Many of them, especially in soil conservation districts, are calling on the Service for assistance in appraising the adequacy of present supplies. Where these supplies need to be supplemented, assistance has been provided in developing additional supplies. Consideration is given to developing surface storage if suitable sites are available, to the use of drainage water where appropriate, to the location and development of wells if adequate groundwater supplies are known to exist, and to other sources of supply. In many sections there is a serious lack of information needed for the development of surface or underground storage and for the development of well supplies.

Legal Aspects of Water Use

Legal factors also influence the use of water for supplemental irrigation. Most of the states in the humid areas do not have laws for the appropriation of water for irrigation. The riparian doctrine generally prevails in the eastern states. Under this law only an owner of lands riparian to a stream may make reasonable use of its water but only on his riparian lands. The law follows the principle of equality, which requires that the body of flowing water become no one's property and that, aside from rather limited use for domestic and agricultural purposes by those above, each riparian owner has the right to have the water flowing down to him in its natural volume and channel unimpaired in quantity or quality. Up to the present time there have been only a few cases of litigation involving water use for irrigation purposes. An expansion of the area irrigated, however, will certainly tend to increase the difficulties. Experience has shown that there is a pressing need for a thorough study of water laws in the eastern states. Evidence to date indicates that present laws should be revised or new laws enacted.

Impact of Irrigation on the Farm Economy

The full development of irrigation potentialities in the humid areas of the United States will have a major impact on the agricultural economy. Irrigation permits the use of improved plant species and seeding mixtures that will lead not only to higher production, but in most cases to better control of soil erosion.

Throughout much of the humid areas, where irrigation is needed to provide moisture for plant growth during critical periods of summer drought, changes in soil fertility practices will be necessary. To justify the expense of the irrigation system close attention toward obtaining the highest possible production per acre will be necessary. Such a system will permit intensification of farming practices with high fertility levels and production of high value crops. This may bring about increases in the number of livestock handled on the farm, or it may make advisable a change in the kinds of livestock.

Supplemental irrigation also makes possible the use of earlier maturing varieties of crops and often two or more truck crops adjusted to market demands, and thus greatly increases the income from the land.

Adequate and efficient use of irrigation offers the possibility of much better utilization of land in accordance with its capabilities. Crops that permit erosion damage can be more completely confined to the classes of land upon which erosion is less severe. Increased yields per acre can be obtained through high fertility and adequate seasonal moisture. Utilization of the more erodible lands for grass and legume production will therefore be much more feasible and practical.

A more balanced production of crops by land classes to meet the feed, cash, and forage requirements of the total farm unit can be anticipated. In extreme cases changes in buildings or equipment may be needed to fully utilize the advantages offered by efficient irrigation.

Future Plans

It is the policy of the Soil Conservation Service to provide technical and other assistance, as available, to irrigation farmers in soil conservation districts in connection with their soil and water conservation programs. While this is now being done, there is need for accelerating both operations and research work in the field of irrigation.

The Service therefore plans to carry out at least the following activities:

1. Make soil conservation surveys and land use capability determinations of the agricultural and other lands. This is necessary to determine the suitability of the land in accordance with the Department of Agriculture's basic conservation objective.

2. Obtain information from various sources as to the availability and suitability of water supplies for farm irrigation.

3. Conduct investigations of community, watershed, or problem areas as a basis for recommending soil and water programs to individuals and groups of farmers.

4. Prepare technically sound plans for farms and groups of farms involving the development, application and use of irrigation water as a part of soil and water conservation.

5. Provide on-site technical services in connection with the installation of irrigation systems and the efficient use of farm water supplies.

6. Provide for additional irrigation specialists in the field, the regional, and Washington offices to assure continued high-quality assistance to farmers and ranchers.

7. Extend to all field employees, where applicable, training in the planning and application of irrigation water to the land.

8. Cooperate with other federal agencies and with state governments and their subdivisions, as well as with water users' organizations, equipment dealers, and others in the sound development, use, and management of the land and water resources, including irrigation where feasible and practical.

9. Assist in disseminating information and providing conservation education pertaining to water use, management and disposal.

10. Conduct, or participate in conducting, in cooperation with the State Experiment Stations, research in such needed fields as the following:

a. Determine by states or regions the water supplies available for supplemental irrigation. The investigations should include both underground and surface water supplies, including storage possibilities of various types.

b. Determine the relationship of sunlight, rainfall, temperature, wind, and humidity to the occurrence and frequency of drought periods. Such hydrologic investigations should be made by states or regions.

c. Determine the rate at which water enters and travels through the various soils under different cultural practices and vegetal covering. Such data are essential in designing an efficient irrigation system.

d. Determine the most suitable amount of soil moisture in terms of field capacity for various areas and soils.

e. Determine the amounts and rates at which water can be applied to various soils under different crops and cultural practices and still avoid soil erosion, sealing of soil surface, leaching, and waterlogging.

f. Determine the effect of the various methods of applying water on crops, soil erosion, soil sealing, and leaching.

g. Determine rate of application and area of distribution of various types of nozzles and water outlets operating under different pipe pressures.

h. Determine most efficient types of pumping units and distribution systems for supplemental irrigation operating under various soil and topographic conditions and with various types of water supply.

i. In sprinkler irrigation determine, for various soils, the effect of drop size on surface sealing and runoff.

j. Determine existing legal rights to surface and groundwater supplies available for supplemental irrigation in the humid states, and develop recommendations for any needed legislation relating to the subject.

k. Determine rates at which various crops use water at different stages of plant growth.

l. Determine the depth of root penetration for various plants in different soils. Such information is needed to determine the depth of soil that should be wetted.

m. Determine the effect of supplemental irrigation on fertilizer requirements of different crops under various soil and climatic conditions.

n. An appraisal of the economic and farm management problems involved in an extensive development of the practice of supplemental irrigation in various sections of the humid region.

APPENDIX 1 - NOTES ON HUMID AREA IRRIGATION BY STATES

Southeastern States

Alabama

The greater number of requests for technical assistance thus far received have originated in the Gulf Coast counties in southern Alabama. These requests have come principally from vegetable, flower, and bulb growers. There is considerable irrigation of vegetable crops in the vicinity of the larger cities (such as Birmingham) where the concentrated population affords a local market. Vegetable crops are also irrigated to a limited extent in the Tennessee Valley of northern Alabama. Numerous requests for assistance with pasture irrigation have been received from farmers throughout the entire state. Interest in pasture irrigation is increasing rapdily. All irrigation is accomplished by the sprinkler method.

Florida

Irrigation is practiced in nearly all counties in Florida. This is due to several factors: a) uneven rainfall distribution; b) low water-holding capacity of the soils; and c) the high value of crops raised. Numerous requests for assistance are being received from all counties within organized soil conservation districts.

In north and west Florida there is an increasing interest in irrigating pasture grasses. Also, in north Florida it has become standard practice to irrigate shade-grown tobacco (a very high-priced crop). The vast majority of the acreage is irrigated. Interest is now developing in the irrigation of bright leaf tobacco. Irrigation in north and west Florida is by the sprinkler method.

In the counties along the lower east coast irrigation of citrus is practiced, using the furrow method. A few growers, however, are experimenting with the sprinkler method in the interest of water conservation and better distribution. Also, in this section vegetables and improved pastures are irrigated by subirrigation--a method whereby the natural water table is periodically raised to the root zone. Farmer interest in pasture irrigation by this method is growing rapidly.

In the counties along the lower west coast of Florida, irrigation of vegetable, flower, and bulb crops is widely practiced, using the subirrigation method. Interest in irrigating pasture grasses by this method is on the increase in this area.

In the muck lands of the Everglades in southern Florida, it has been the custom of practicing control of soil moisture for many years. Vast acreage of sugar cane, vegetable crops, and pasture grasses are grown on these lands.

Georgia

In the counties bordering the Atlantic Coast below Savannah, irrigation of vegetable crops is being practiced and farmer interest appears to be on the increase. In several counties of southern Georgia, the irrigation of shade-grown tobacco has become a common practice and farmer interest is spreading

to the irrigation of bright leaf tobacco. In the Coastal Plain counties of Georgia, numerous requests for assistance with pasture irrigation problems have been received. Irrigation in Georgia is confined to the sprinkler metho

Kentucky

Irrigation in Kentucky is largely confined to vegetable and nursery crops in the near vicinity of the larger cities, such as Louisville. A few scattered requests for assistance have originated in other sections of the state. Inte est appears to be confined to the sprinkler method.

Mississippi

Irrigation here is largely used for growing rice in the Delta area. Lately, however, there has been some interest shown in irrigating pasture grasses on the same land following rice. It is proposed to use the same modified basin system for pasture irrigation but little has been done thus far. Elsewhere in the state only a very few requests for assistance with irrigation problems have been received.

North Carolina

In the counties bordering on the Atlantic Coast, irrigation of Irish potatoes and some vegetable crops is practiced to a limited extent. The practice is expected to grow as farmers become acquainted with resulting benefits. The sprinkler method is generally used, although a very few growers are using the subirrigation method without much success.

In the Upper Coastal Plain and Piedmont counties, the primary interest is in irrigating pasture grasses and alfalfa. This practice is spreading rapidly where water supplies are available. A few growers in these areas are becoming interested in the irrigation of bright leaf tobacco and more may be expected as the knowledge of its benefits becomes more widespread. One grower had remarkable success in irrigating apples this year. The sprinkler method is used exclusively.

South Carolina

In the counties bordering on the Atlantic Coast, many vegetable crops are irrigated. In the Upper Coastal Plain counties, a number of bright leaf tobacco growers are experimenting with irrigation. In this area and in the Piedmont area, considerable interest is being shown in pasture irrigation. In the Upper Piedmont counties, the practice of irrigating peaches is fast growing. The sprinkler method is used exclusively in South Carolina.

Tennessee

Small acreages of vegetable crops and pasture grasses are irrigated in western Tennessee around Memphis. Several requests for assistance with irrigation of pasture grasses and forage crops have originated in the area around Nashville although little irrigation has been put into practice. There are small acreage of truck crops and pasture grasses irrigated in the TVA area of western Tennes In this state, irrigation is exclusively by the sprinkler method.

Virginia

Vegetable crops are irrigated rather widely on the eastern shore of Virginia, and to a much lesser extent in the counties bordering on the Atlantic Ocean. Farther inland, in south central Virginia, some interest has been shown in the irrigation of bright leaf and burley tobacco, although little has been actually accomplished. In the Piedmont and valley areas of the state, considerable interest has been manifested in the irrigation of pasture grasses and forage crops. Irrigation in Virginia is by the sprinkler method.

New England States

Interest in supplemental irrigation is scattered throughout Long Island, New York, the Connecticut River Valley in Massachusetts and Connecticut, truck areas in New Jersey, and a small truck area south of Buffalo, New York. Outside these areas the practice is scattered and limited to some of the more progressive or experimentally inclined farmers. The total number of these cases is quite significant.

Experience in Rhode Island has indicated a need for study and probable revisions of water laws. Any appreciable increase in supplemental irrigation will create water shortages in smaller streams with resultant litigation. In practically all cases present laws will seriously hamper the courts in the effort to establish an equitable apportionment.

Mississippi Valley States

Illinois

A quick inventory indicates an estimated 5,900 acres being irrigated in Illinois. Some estimates run as high as 9,000 acres. Most of the irrigated land is around the large cities, primarily in the Chicago area. Gladiolus and truck crops predominate under irrigation. A few farmers are more or less experimenting with irrigation of pastures, ladino clover, and seed corn.

Indiana

The interest in irrigation at present seems to be centered in the northern and southern tiers of counties in the state. Except for truck farms in the Terre Haute area in Vermillion and Vigo counties, there seems to be little interest in irrigation throughout the large area of dark-colored soils, including Prairie, of central Indiana.

Iowa

All irrigation is of the gravity type. The principal crop irrigated has been sweet corn. Some reports indicated two applications of water increased the yield $2\frac{1}{2}$ to 3 tons per acre.

Michigan

It is not known if any gravity irrigation systems are in operation in Michigan. Subsurface irrigation by water table control is used on the muck land. All other irrigation is by sprinkler. It is estimated by Michigan State College that about 1,500 systems are in use.

Minnesota

The Minnesota Department of Drainage and Waters reports 52 applications for permits for the irrigation of 4,057 acres from 1938 to 1951 (Jan. 30, 1951).

Under state statutes, it is unlawful to appropriate or use any waters of the state (surface or underground) without written permission of the Commissioner of Conservation.

This does not apply to the use of waters for domestic purposes serving at any time less than 25 persons, or to the use of waters for any purpose originating within the geographical limits of any municipality, nor to any beneficial uses and rights in existence on July 1, 1937.

In issuing permits for the appropriation of water from lakes or streams, ripari rights of other owners of lands abutting on such waters are considered, as well as the effects on normal beneficial use of such waters by the general public. A total of 90 permits have been issued in Minnesota.

Missouri

A survey in 1950 by Missouri Agricultural Engineering Department indicated tha were 225 irrigators in Missouri, of whom 150 were in the vicinity of St. Louis. Other areas of concentration were around Kansas City and the Springfield-Joplin area of southwestern Missouri. Approximately 200 of the systems were for truck crops and 25 for field crops. Counties from which the Soil Conservation Servic has received requests for irrigation work are: Pemiscot, Greene, Dent, Newton, Pike, and Harrison.

Ohio

Irrigation is being used by Ohio farmers in the production of vegetables, orchards, and general farming. The vegetable growers are grouped along the Ohio and Muskingum Rivers, around Cincinnati, and in northern and northeastern Ohio. Potato growers are more widely scattered. Fruit growers, also, are widely scattered. The Lake Erie region and southern Ohio are the principal centers.

Practically all of the irrigation in Ohio is by the sprinkler system rather than by gravity.

Nebraska

During the past ten years there has been a general tendency for irrigation to move eastward in the state of Nebraska and, to a lesser degree, in Kansas and South Dakota. It is likely that interest in irrigation will gradually increas east of the 97th Meridian - especially in areas where ample water supplies are available. This is in line with the trend of the past ten years.

Western Gulf States

Most of the supplemental irrigation development in the humid areas of Arkansas, Louisiana, Texas, and Oklahoma has occurred during recent years. This development is proceeding at an increasing rate as more farmers learn they can increase the production of certain kinds of crops materially by applying relatively small amounts of irrigation water at the right times. The principal crops receiving supplemental irrigation are strawberries, truck crops, hay and pasture, corn, cotton, and soybeans. Table 2 shows the acreage of these crops currently irrigated by states, by source of water supply and by type of irrigation, and the acreage of supplemental irrigation for which the Service has provided technical assistance in the development or improvement of irrigation facilities.

In strawberry production supplemental irrigation is used principally in establishing new plantings and to maintain vigor in old plants during the hot summer months. Some irrigations are applied to improve berry quality. It is not unusual to more than double strawberry production by efficient supplemental irrigation.

Truck crops are irrigated to supplement rainfall during the normal growing season, thereby increasing yields materially, and to produce additional crops during "off" seasons when not enough rainfall can be expected to make a crop. The market price usually is sufficiently higher during "off" seasons to make it profitable to irrigate even though the crop yields are not as great as those produced during the normal growing season.

Irrigation produces profitable increases in hay and pasture yields almost every year. The availability of succulent green forage during the months of July, August, and September can be increased by irrigation in some parts of the area almost every year.

Under normal rates of fertilization corn makes a profitable response to irrigation two years out of three. If heavy rates of fertilization are used, irrigation of corn is profitable almost every year.

Irrigation of cotton and soybeans seldom produces sufficient increases in yields to justify the additional cost. However, where it is possible to apply irrigation water at little cost to furnish needed moisture at optimum planting dates this may be profitable.

In contrast to the rice irrigation areas, most of the supplemental irrigation areas have been recently developed and the operators have little or no experience with irrigation farming. The development of an adequate water supply is often a difficult problem, requiring technical knowledge and assistance for its solution. The frequent occurrence of high intensity rainfall increases the difficulty of irrigation development, making it necessary that adequate erosion control measures and drainage facilities be integrated with the drainage system.

The Service has given technical assistance in the development of three-fourths of the supplemental irrigation in eastern Texas, and in almost one-half of similar development in Arkansas.

Table 2

SUPPLEMENTAL IRRIGATION IN HUMID AREAS

ACRES

WESTERN GULF REGION

	Arkansas	Louisiana	Humid Portion of Oklahoma	Humid Portion of Texas	Total
Supplemental Irrigation 1/	20,000	11,300	7,700	3,800	42,800
Water Source:					
Ground	18,000	10,000	2,250	1,200	31,450
Surface	2,000	1,300	5,450	2,600	11,350
Crops:					
Cotton	1,600	160	-	1,200	2,960
Corn	1,000	660	-	100	1,760
Hay & pasture	15,000	420	5,700	1,700	22,820
Truck & berries	2,400	10,060	2,000	800	15,260
Type of Irrigation:					
Border	15,000	135	3,700	550	19,385
Row	3,175	10,050	1,150	800	15,175
Sprinkler	1,825	1,115	2,850	2,450	8,240
SCS assistance to 6/30/51	9,374	721	1,003	2,858	13,956

1/ Does not include supplemental irrigation of hay and pasture on developed rice lands.

The planning of a supplemental irrigation system includes the selection of a method of irrigation suited to the soil characteristics, climate, topography, water supply and the crops to be grown. Borders, rows and sprinklers are the most common methods of supplemental irrigation.

Pacific Coast States

Irrigation in the western areas of Washington, Oregon, and California is a different problem than the supplemental irrigation practiced in the eastern part of the United States. Although these western areas are considered to have a humid climate, with annual precipitation of over 100 inches in some localities, the summer growing season is usually dry. Irrigation permits a wider choice of crops and farm enterprises. It also results in increased production of many crops that have been successfully grown without irrigation. When farm enterprises have been changed as a result of irrigation, generally the irrigation can no longer be considered as a supplement to natural precipitation, but instead becomes a vital factor in crop production. In this respect these western counties are not greatly different from the more arid irrigated areas of the region. Occasionally summer rains may reduce the number of irrigations required, but seldom is a major portion of the crop moisture requirement provided by such rains.

APPENDIX 2 - SUPPLEMENTAL IRRIGATION RESEARCH

The Division of Drainage and Water Control of the Soil Conservation Service, which was transferred to the Service in 1939, has conducted investigations relating to supplemental irrigation research since 1900. The early work was aimed at developing cheaper and more effective irrigation equipment such as pumping installations, gates, valves, riser pipes, etc., used in connection with surface irrigation. Investigations were also carried on to develop spray irrigation from fixed pipe lines. The work consisted primarily of determining the requirements of pumping plants; most efficient size of pipe for different lengths of line; most efficient pressure at which to operate system; proper spacing and size of nozzle; best height of pipe supports for different crops, etc. In addition data were obtained relating to the effect of applying various amounts of water at various rates; dependability of various types of equipment, labor requirements, convenience of operation, investment and operating costs; and benefits resulting from irrigation.

These early investigations were largely conducted in the States of New Jersey, Wisconsin, and Florida, and the results secured have been published in the following bulletins:

Office of Experiment Station Bulletins
87 Irrigation in New Jersey. Edw. B. Voorhees. 1900.
148 Report on Irrigation Investigations in Humid Sections of the U. S. in 1903. E. B. Voorhees, H. J. Waters, and A. B. Crane.
167 Irrigation in the North Atlantic States. A. J. Bowie, Jr., 1906.

Department Bulletins
462 Irrigation in Florida. F. W. Stanley. 1917.
495 Spray Irrigation. Milo B. Williams. 1917.

Circulars
195 Tests of Spray Irrigation Equipment. F. E. Staebner. 1931.

Farmers Bulletins
899 Surface Irrigation for Eastern Farms. F. W. Stanley. 1917.
1529 Spray Irrigation in Eastern States. G. A. Mitchell and F. E. Staebner, 1927
1635 Surface Irrigation in the Eastern States. F. E. Staebner. 1930.
1846 Supplemental Irrigation. F. E. Staebner. 1940.

Since 1940 the Service has conducted supplemental irrigation investigations. The objectives of the work are:

(1) To determine the relative effectiveness and economy of different methods of applying water for irrigation in the region where rainfall during the growing season usually supplies most or all of the moisture used by crops and to develop more practical methods and better equipment for irrigation operation.

(2) To determine the degree of need for supplemental irrigation and the probable benefits therefrom, in different parts of the humid region, and to develop a practical method of calculating such need for particular localities.

Investigations under this work project are now being carried on at the following locations. All of the work is conducted in cooperation with the interested State Agricultural Experiment Station.

Alabama

Auburn, Ala.

In cooperation with the Alabama Agricultural Experiment Station supplemental irrigation investigations were started in 1951 to establish rates of application and quantity of water to be supplied by supplemental irrigation to crops under various soil conditions. This involves determination of infiltration rates, retention of moisture available for plant use, and percolation rates of major soil types in the State.

Investigations have also been started to establish equipment design factors applicable to supplemental irrigation systems, and to determine the initial cost, and cost of operation of supplemental irrigation equipment for single and multiple use on the farm. An experiment has been started to determine the feasibility of irrigation of crimson clover planted in July to provide early fall grazing and early seed harvest.

Florida

Homestead, Fla.

Supplemental irrigation investigations conducted in cooperation with the Florida Agricultural Experiment Station are underway to: (a) Determine the area of application and efficiency of operation of various types of equipment; (b) determine the most effective rate of application and amount of water applied per irrigation on the Rockland and marl areas of southern Florida; and (c) determine the most effective irrigation cycle for the area.

Investigations show that the moisture content of the soil 24 hours after a one-inch application of water is as high as it is after a three-inch application. This development has resulted in farmers reducing the amount of water applied per irrigation from 2 or 3 inches to 1 inch which reduces cost of operating irrigation equipment by at least 50 percent and reduces fertilizer losses due to leaching. Tests show that distribution of water by large nozzles is not uniform.

Lake Alfred, Fla.

In cooperation with the Florida Agricultural Experiment Station investigations are underway to: (a) Determine the effects of applying irrigation water in different amounts and rates, and by different methods, upon the moisture content of the soil, and on the quantity and quality of fruit produced in citrus groves in the sandy land area of central Florida; (b) to develop methods and equipment for improving the wettability of the soil under various methods of irrigation; (c) to investigate the sources and amounts of water available for irrigation; and (d) to develop improvements in equipment used in irrigation and in methods of applying irrigation water.

Investigations indicate that a rate of application of 1 inch per hour can be made without resulting in surface runoff and erosion, and is more effective than heavier rates. An application of 1½ inches of water per irrigation is just as effective as 3 inches as far as soil moisture and crop yields are concerned and greatly reduces losses due to leaching. Reduction of funds has limited the Service's contribution on this project to the furnishing of technical equipment. The experiment station is continuing the collection of records with the hope that the SCS staff will be able to analyze the data obtained.

Georgia

Athens, Ga.

In cooperation with the Georgia Agricultural Experiment Station and the University of Georgia, the following supplemental irrigation investigations are underway: (a) Climatological studies to determine drought frequencies and need for irrigation; (b) availability of water supplies for irrigation; (c) to determine efficiencies of various types of equipment; (d) to investigate infiltration rates and effective soil-moisture range of Piedmont soils, as a basis for applying irrigation water; (e)to determine the most effective and efficient rate of application and amount of water to be applied per irrigation to maintain satisfactory moisture conditions under various crops and pastures; and (f) to investigate cost of operating irrigation equipment under farm conditions in the Piedmont area, in orchards, cultivated fields, and pastures.

Under this project the results of a study to determine frequency of droughts in Georgia have been published by the University of Georgia.

Illinois

Dixon Springs, Ill.

In cooperation with the Illinois Agricultural Experiment Station investigations are underway to determine the need for and utilization of water applied by supplemental irrigation to ladino clover pasture. During 1948 and 1949 supplemental irrigation was applied to a 5-acre ladino clover pasture. A nonirrigated 5-acre tract was used as a check. The soils belong to the Grenada catena.

Forage production was increased by application of both 6 inches and 12 inches of water. Indications are that irrigation should start when available soil moisture in upper 12 inches of soil is reduced to about 35 percent of the amount of available moisture that the soil is capable of retaining at field capacity.

Indiana

Walkerton, Ind.

Subirrigation of muck land, complementary to controlled drainage of truck crops, mint, and potatoes. Investigations show that satisfactory control of groundwater elevation requires intensive tiling and close control of water supply. Results to date indicate that the maintenance of a water table depth of 30 to 33 inches results in best yields for most crops.

Maine

Orono, Maine

Supplemental irrigation investigations conducted in cooperation with the Maine Agricultural Experiment Station have been underway since 1946 to determine relation between irrigation and tuber size of potatoes. In some cases there has been considerable increase in yield due to irrigation but this has not been true in all cases.

Experiments were started in 1949 on the irrigation of pastures and on low-bush blue berries. The blue berries were on a sandy loam soil. The rainfall was ample last season and there was no improvement in either yield or quality due to irrigation.

Maryland

Beltsville, Md.

In cooperation with Maryland Agricultural Experiment Station supplemental irrigation studies have been carried on during the past year in connection with tobacco on ridged rows. The experiment was conducted on Muirkirk loam sand. Preliminary results indicate that supplemental irrigation must be used with care even in dry years and that time of application is very important with tobacco. The ratio of bright or high quality tobacco was increased and quality as judged by burning tests was improved by irrigation.

Missouri

McCredie, Mo.

In cooperation with the Missouri Agricultural Experiment Station supplemental irrigation investigations were started in 1948 on typical claypan soils. Primary objectives are to determine erosion hazards of irrigation on land subject to high intensity storms; and to determine increased yields resulting from adequate water. A corn-soybeans-wheat-clover-and-timothy rotation with and without soil treatment is now under test. Other objectives are to determine the most practical time and means for supplying additional water to farm crops, and to determine the practical value of farm ponds as a source of supply for irrigation water in the claypan area.

New Jersey

New Brunswick, N. J.

In cooperation with the New Jersey Agricultural Experiment Station supplemental irrigation investigations are being carried on to determine the: (a) effects of crop rotations and supplemental irrigation on physical conditions of potato soils; (b) effects of crop rotations and supplemental irrigation on runoff, soil loss, and physical condition of soil in truck crop rotation; and (c) supplemental irrigation of pastures.

Under (a) an experimental area is located on Sassafras loam soil. Potatoes are grown in a 2-year rotation with wheat, and in a 3-year rotation with wheat and clover. All treatments are in duplicate on large plots. Plots are irrigated when soil-moisture tension at a depth of 6 inches is between 15 and 20 inches of mercury. Results are measured in terms of physical soil

conditions and by crop yield. It has been found that rate of application of water cannot exceed 0.5 inch per hour if runoff and erosion are to be avoided on Sassafras loam. Potato yields were not significantly affected by irrigation during 1946, 1947, and 1948. Yields were doubled during 1949.

Under (b) experiments are located on Sassafras sandy loam of about 4 percent slope. Sweet corn is grown in a 3-year rotation including 2 years of sweet corn and a year of clover grass sod. All treatments are in duplicate with and without supplemental irrigation. Study has been in operation only one year during which crop yields were increased about 20 percent. As studies continue results will be measured in terms of physical condition of soil, runoff, and soil losses, as well as crop yields. Under (c) a 3-year study on an alfalfa-ladino-brome grass area of loamy sand(probably Evesboro) in so. N. J. No significant increases in forage production were obtained by irrigation during 1947 and 1948. A 14 percent increase was obtained in 1949. However, cost figures indicate value of increase was less than cost of irrigation operations.

During 1948 irrigation was applied on native bluegrass and on ladino clover-orchard grass pasture areas in northern New Jersey on a shale loam (Nassau or Dutchess). No increase was obtained on the bluegrass pasture. The improved orchard grass-ladino clover pasture showed a 37 percent increase in yield where irrigated.

New York

Arnot, N. Y.

In cooperation with the New York State Agricultural Experiment Station supplemental irrigation investigations have been underway since 1945 on Clarkson loam, Alton stoney loam, Amboy silt loam, and Ontario silt loam soils. Preliminary work was carried on with beets, cabbage and corn during 1945 and 1947. In 1948 and 1949 work was on tomatoes. Indications are that blossom-end rot can be materially reduced by supplemental irrigation. Larger tomatoes and greater yields are obtained. The ripening of tomatoes is delayed and quality somewhat reduced by supplemental irrigation. Snap beans gave an increase yield of 1,670 lbs. per acre during 1948.

Experiments have been planned with the Vegetable Crops Division of the Experiment Station to extend over a period of 10 years.

North Carolina

Raleigh, N. C.

In cooperation with the North Carolina Agricultural Experiment Station a pump and 300 feet of portable irrigation pipe have been purchased and plans made for running a few preliminary trials on the irrigation of tobacco. It is planned later to expand the program to include the irrigation of truck crops and pasture. The tobacco plots were set up for the 1949 season, but the rainfall distribution was such that the supplemental irrigation was not required.

Ohio

Coshocton, Ohio

In cooperation with the Ohio Agricultural Experiment Station data are being obtained from lysimeter set-ups that are directly applicable to supplemental irrigation problems for that section of the country. Such information consists of climatological data; daily and hourly values of evapo-transpiration and condensation-absorption; daily records of soil moisture; history of cropping operations; rates and amounts of leaching, and plant nutrient losses; crop yields; and summary of water used by crops.

Puerto Rico

Rio Piedras

In cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering investigations are under way on the following working plans:

1. The relationship of water application efficiencies to prevailing methods of water application and management practices in Puerto Rico.

2. The water requirements and consumptive use of water by crops in the sub-humid area of Puerto Rico.

It has been learned that present methods of water application are generally highly inefficient. They permit the loss of about 75 percent of the water stored for irrigation purposes. Certain practices have been shown to be much more efficient than others. Advanced planning, land preparation, longer runs, revised planting practices, properly designed sprinkler systems, and improved evaluation of soil-moisture conditions all offer promise of greatly increased efficiency.

Work on plan 2 has so far been limited to studies with sugarcane. It include a complete weather station and involves both tank and field studies. The results show that highly fertilized cane is sensitive to moisture-tension levels within the range of water availability. Also, what appears to be a satisfactory method has been developed for using either tensiometers or fibre glass soil resistant units for the timing of irrigation, at least on certain soil types. All results are being correlated with soil-profile studies to obtain a clearer understanding of what happens during cycles of wetting and drying and of crop growth and production. Santa Isabel silty clay and San Anton clay with associated soil-type variations are the main soils involved in present studies.

South Carolina

Clemson, S. C.

In cooperation with the South Carolina Agricultural Experiment Station investigations have been outlined to determine:

1. Optimum soil-moisture content for maximum production of selected crops, and selected soils.

2. The total amount of water necessary to maintain a specific soil-moisture content between the wilting point and field capacity of selected soils with selected crops.

3. The effects of soil moisture on crop quality.

4. The time to irrigate selected crops based on lowest soil-moisture content without injury to crop.

5. The feasibility of supplemental irrigation from an economical viewpoint.

6. The most effective distribution and spacing of various types of sprinklers.

7. The adaptation of various types of irrigation equipment to field conditions.

To date infiltration measurements have been made on soils in truck farming areas near Charleston and peach orchards near Spartanburg to furnish information for predicting the application rates that could be used with sprinkler irrigation systems on these soils. Infiltration rates of freshly cultivated soils at the end of one hour of rainfall ranged from 0.48 to 1.05-inch per hour for truck soils and 0.11 to 0.60 inch per hour for the peach orchard soils. Cecil sandy loam with a good growth of ladino clover had an infiltration rate in excess of 2.25 inches per hour at the end of 60 minutes of rainfall while the same soil in clean-tilled condition in an adjoining tree row interval had an infiltration rate of 0.60 inch per hour.

The available water capacities of each horizon of 43 soil types have been determined and reported in terms of surface inches of available water the soil horizon can hold per inch of depth. Soils having highly oxidized, strongly flocculated B horizons as in the case of Cecil, Lloyd, and Norfolk soils had relatively low available water capacities, usually about 0.10 inch per inch of depth; while soils with the clay in a more dispersed condition had much higher available water capacities. Iredell B. horizon with value of 0.315 inch per inch of depth had the highest available water capacity of any soil tested.

An experiment to determine the response of corn to irrigation and to evaluate certain soil-moisture relations during the growth of corn was started in 1946. The average amount of irrigation water required during the 4-year period was 4.69 inches per corn growing season which produced an average annual increase of 33 bushels per acre. The four corn varieties irrigated varied considerably in yields produced but the yields of the different varieties were in the same order with and without irrigation. The frequency of irrigation of corn on Hiawasses sandy loam has tenatively been determined to be 8 or 9 days. When the soil-moisture content was initially at field capacity, 50 percent of the available moisture is exhausted at the 8-inch depth during this period.

Virginia

Blacksburg, Va.

In cooperation with the Virginia Agricultural Experiment Station supplemental irrigation investigations have been started having the following objectives:

1. To determine the desirable frequency, rate, and total amount of supplemental irrigation for truck crops, field crops, and pastures.

2. To study existing irrigation equipment as to durability, water placement, and size of units; and to develop improved design where possible.

3. To determine the effect of irrigation on erosion problems and on the development of effective land use patterns.

4. To establish the conditions which govern the economic practicability of supplemental irrigation on different field crops, soils and topography under Virginia climatic conditions.

5. To determine the effectiveness of supplemental irrigation on the nutritive content of selected crops and on prolonged maintenance and composition of yields.

6. To determine the effect of supplemental irrigation on soil structure and on the utilization and rate of fertilizer elements.

7. To determine the effect of supplemental irrigation on meat animal production from permanent pastures.

The investigations were started in 1946 in Montgomery Co., Va., on Litz acid shale. Alfalfa was the first crop placed under study. In 1946 the increased yield of alfalfa on the irrigated plots, as compared with the nonirrigated plots amounted to approximately 3,000 lbs. per acre, barn dry-basis. In 1947 ample rainfall throughout the growing season made it unnecessary to irrigate. Records were incomplete in 1948 and in 1949 there was ample rain during the growing season and there was no significant difference between irrigated and nonirrigated plots. In 1948 an experimental irrigation set-up was established on the animal husbandry farm of the experiment station and in 1949 investigations were conducted on the irrigation of corn, burley tobacco and clover. Corn yield on the irrigated plots averaged 98 bushels per acre compared with 65 bushels per acre from the nonirrigated check plots. The experiments were located on Groseclose silt loam and Greendale silt loam. There are definite indications that irrigation materially improved the quality of burley tobacco; however, the cooperating agency failed to keep sufficient detailed records to justify publication.

The following list of bulletins and articles outline the results being secured at these current projects:

Technical Bulletin

1050 Agricultural Hydrology as Evaluated by Monolith Lysimeters. L. L. Harrold and F. R. Dreibelbis. In GPO office.

State Bulletin

Preliminary Climatological Study of Relationship Between Amount of Rainfall and Drought Occurrences in Georgia. Lee D. Dumm. Ga. St. Bulletin. 1946.

Recent articles by SCS staff

Supplemental Irrigation. J. R. Carreker and W. B. Land. Ann. Report, Research and Investigational Activities. Col. Agr., U. Ga. Vol. L., No. 10g. June 1950, pp. 43-45.

Fertilizer Application in Irrigation Water. J. R. Carreker and W. B. Land. Sub. Jan. 3, 1950 for pub. and pres. Amer. Soc. Agr. Engineers SW Section mtg. Biloxi, Miss.

Agricultural Phases of Drouth. John Lamb, Jr., Sub. Jan. 1950 for pub. in Ag. Eng.

Designing an Irrigation System. J. R. Carreker. Sub. Oct. 19, 1949, in Progressive Farmer.

Using Irrigation Equipment to Prevent Losses. J. R. Carreker. Sub. Oct. 19, 1949, for pub. in Progressive Farmer.

Supplemental Irrigation of Pastures in the Southeast. J. R. Carreker. Pres. Baton Rouge, La., Jan. 31, 1949, at mtg. So. Section Amer. Dairy Assn.

Supplemental Irrigation in Georgia. J. R. Carreker and W. J. Liddell. Sub. Mar. 29, 1949 for Ga. Academy of Science mtg. April 22-23.

Results of Irrigation Research in Georgia - Part I. J. R. Carreker and W. J. Liddell. Agr. Eng. 29: 243-244, 250. 1948.

Results of Irrigation Research in Georgia - Part II. J. R. Carreker and W. J. Liddell. Agr. Eng. 29: 301-302. 1948.

Supplemental Irrigation in the Southeast. J. R. Carreker. Sub. Oct. 22, 1948, an address for Agr. Development Committee of the Southeastern Electric Exchange.

Report of Steering Committee on Supplemental Irrigation. James Turnbull. Sub. Jan. 17, 1949, for pres. SW Sec. Amer. Soc. Agr. Eng. Jan. 1949.

The Effect of Irrigation on Fruit Yields. James Turnbull. Sub. Aug. 24, 1948, for pres. at 75th Annual Citrus Growers Institute at Camp McQuarrie on Sept. 2, 1948.

Supplemental Irrigation in Virginia. J. H. Lillard, J. W. Propst, and T. W. Edminster. Sub. Feb. 6, 1948, for pres. in Irrigation Symposium at So. Sec. Amer. Soc. Agr. Eng.

Preliminary Results of Supplemental Irrigation with a Portable Sprinkler Syst
W. J. Liddell. Sub. July 12, 1947, for pub. in bulletin Research and Investi
tional Activities of the Col. of Agr., Annual Report of Col., Athens, Ga.

Supplemental Irrigation Research in Georgia. J. R. Carreker and W. J. Liddell
Submitted Nov. 1947 for publication and presented Amer. Soc. Agr. Eng. mtg. i
Chicago. Dec. 15, 1947.

The Status of Irrigation in Florida. James Turnbull. Pres. at SE Sec. Amer.
Soc. Agr. Eng. Feb. 12, 1947.

Relationship Between Amount of Rainfall and Drought Occurrences in Georgia.
L. D. Dumm and W. J. Liddell. Submitted June 3, 1946, for publication in
An. Col. of Agr. Res. Bul.

Irrigation Equipment for Vegetable Growers. Sub. Dec. 26, 1944, for pres.
and pub. New Jersey Hort. Soc., Trenton, N. J.